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Forest Service

Tongass National Forest

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November 2003

Greens Creek Tailings Disposal

Final Environmental Impact Statement

Volume I

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File Code: 1950-3/2810
Date: October 24, 2003

Dear Commenter:

Enclosed are the Greens Creek Tailings Disposal Final Environmental Impact Statement and Record of Decision (FEIS/ROD).

The complete FEIS/ROD is also available via the internet on the Greens Creek website and will be available on the website until December 31, 2003.

www.greenscreekeis.com

Thank you for your participation in this project. For additional information contact:

Jeff DeFreest
8465 Old Dairy Road
Juneau, AK 99801
(907) 790-7457

Sincerely,

FORREST COLE
Forest Supervisor

Enclosure: Greens Creek Tailings Disposal FEIS/ROD

Record of Decision

Greens Creek Tailings Disposal

USDA Forest Service
Tongass National Forest
Admiralty Island National Monument

Introduction

This Record of Decision documents my selection of Alternative C that will be used to amend the General Plan of Operations (GPO) for the Kennecott Greens Creek Mining Company (KGCMC). The purpose and need of this analysis was to consider changes to the approved Plan of Operations regarding tailings disposal in order to allow for continued operations.

Background

The Greens Creek Mine is an underground metals mine near Hawk Inlet on northern Admiralty Island. It is located approximately 18 miles southwest of Juneau, Alaska. The mine is situated in the Greens Creek watershed within the Admiralty Island National Monument, Tongass National Forest.

The purpose and need for the proposed action is to consider changes to the General Plan of Operations for the Kennecott Greens Creek Mining Company regarding tailings disposal in order to allow for continued operations.

Based on known ore reserves and the current rate of production, the Greens Creek Mine has a remaining life of approximately 12 years. In addition to known ore reserves, past success in exploring indicates that more deposits may be discovered in the area. KGCMC has indicated that such discoveries could extend the mine life an additional 10 years for a total remaining 22 years. Based on known and anticipated ore reserves and the current rate of surface tailings placement KGCMC requires above-ground tailings disposal capacity for approximately 6 million tons of additional tailings. Under the current permit and current rate of production the existing tailings facility has space for approximately two years of tailings disposal. Consequently, additional disposal capacity is needed to continue operations.

Based on that need, in January 2001, KGCMC submitted an application to the Forest Service requesting a modification of the existing General Plan of Operations for expansion of the existing tailings facility.

Decision

This decision is based upon the analysis and evaluations in the Final Environmental Impact Statement as well as information incorporated by reference from previous Environmental Analyses in 1983, 1987 and 1992.

After reviewing the alternatives, I have decided to select Alternative C which will modify the GPO to allow expansion of the existing tailings disposal facility to the east of the present location and require a continuous carbon addition to the tailings.

Expansion to the east will minimize both the lease area and the disturbed area within the Admiralty Island National Monument. A continuous addition of carbon to the tailings will be required to provide greater assurance of long-term chemical stability of the tailings in order to meet water quality requirements. A sulfate reduction monitoring plan (SRMP) will be implemented during the first thirty months following modification of the GPO. The study will determine how much carbon is necessary to ensure continued sulfate reduction, the form of carbon that will best meet the goal of sulfate reduction, and the manner in which carbon should be incorporated into the tailings. The SRMP will also consider potential application to the existing tailings placed prior to this decision.

Like all action alternatives, Alternative C includes:

- Installation of a layered cover, liners and vegetated layer over tailings piles following mine operations to be approved by the Alaska Department of Environmental Conservation and the Forest Service.
- Control of routing and separation of contact and non-contact water in drainage systems
- Treatment of stormwater and contact water to meet Alaska Water Quality Standards (AWQS)
- Construction of earthen berms to protect tailings piles and prevent infiltration of stormwater
- Water Treatment – Effluent from outfall 001 and 002 will be treated to meet AWQS for metals and other constituents. All contact water discharged from the site must meet AWQS.
- Sedimentation controls

Monitoring and Mitigation

During the 30 months following the issuance of the ROD, KGCMC will evaluate sulfate reduction presently occurring within the tailings pile. This evaluation will determine 1) the amount and type of carbon needed to ensure that the sulfate reduction processes continues following mine closure and 2) if the reduction is occurring at a rate sufficient to meet NPDES limits and/or AWQS for water discharge directly (no mixing zone) into nearby surface or groundwater using freshwater quality-based effluent limits for metals.

In connection with requirements of the NPDES permit, monitoring of seafloor sediment and biota is also required by the EPA. As a result of consultation with NMFS, the EPA, and ADEC regarding Essential Fish Habitat (EFH), a monitoring plan for EFH is being developed and will become part of the KGCMC General Plan of Operations. The monitoring plan will incorporate the conservation recommendations by NMFS for sampling of marine biota and sediments, as well as addressing contaminated sediments from a 1989 concentrate spill at the ore ship loading dock.

The GPO and ADEC Waste Management Permit specify visual, groundwater, surface water, leachate, biological, and post closure monitoring requirements. For water quality monitoring under this plan, KGCMC analyzes water quality samples from several wells upgradient and downgradient from the tailings pile.

Modifications to the existing freshwater monitoring plan will be made to account for the change in the tailings lease boundary. The duration of monitoring is set by the ADEC in the Waste Management Permit. After closure, prior to cessation of monitoring, KGCMC must demonstrate ".... that all downgradient monitoring stations have been in compliance with Alaska Water Quality Standards (AWQS) for at least 3 years. Additionally, results of monitoring at internal sites must corroborate the finding that water quality downgradient of the facility will not change in the foreseeable future. DEC retains the right to extend monitoring requirements as long as it is needed".

If monitoring detects exceedences or violations, contingency plans in the ADEC Waste Management Permit are required to mitigate the specific violation. Concurrent reclamation and reclamation after closure including wetland creation and road removal are also mitigation measures built into the GPO and Waste Management Permit.

Permits, Licenses and Certifications

To proceed with expansion of the tailings area as addressed in this EIS, various permits, licenses and certifications must be obtained from federal, state and municipal agencies. The following permits will be obtained:

U.S. Forest Service
Approval of amended GPO and Reclamation Bond.
Approval of expansion of lease area and changes to existing Special Use Permits.

U.S. Army Corps of Engineers
Approval of discharge of dredged or fill material into waters of the United States (Section 404 of the Clean Water Act of 1977, as amended).

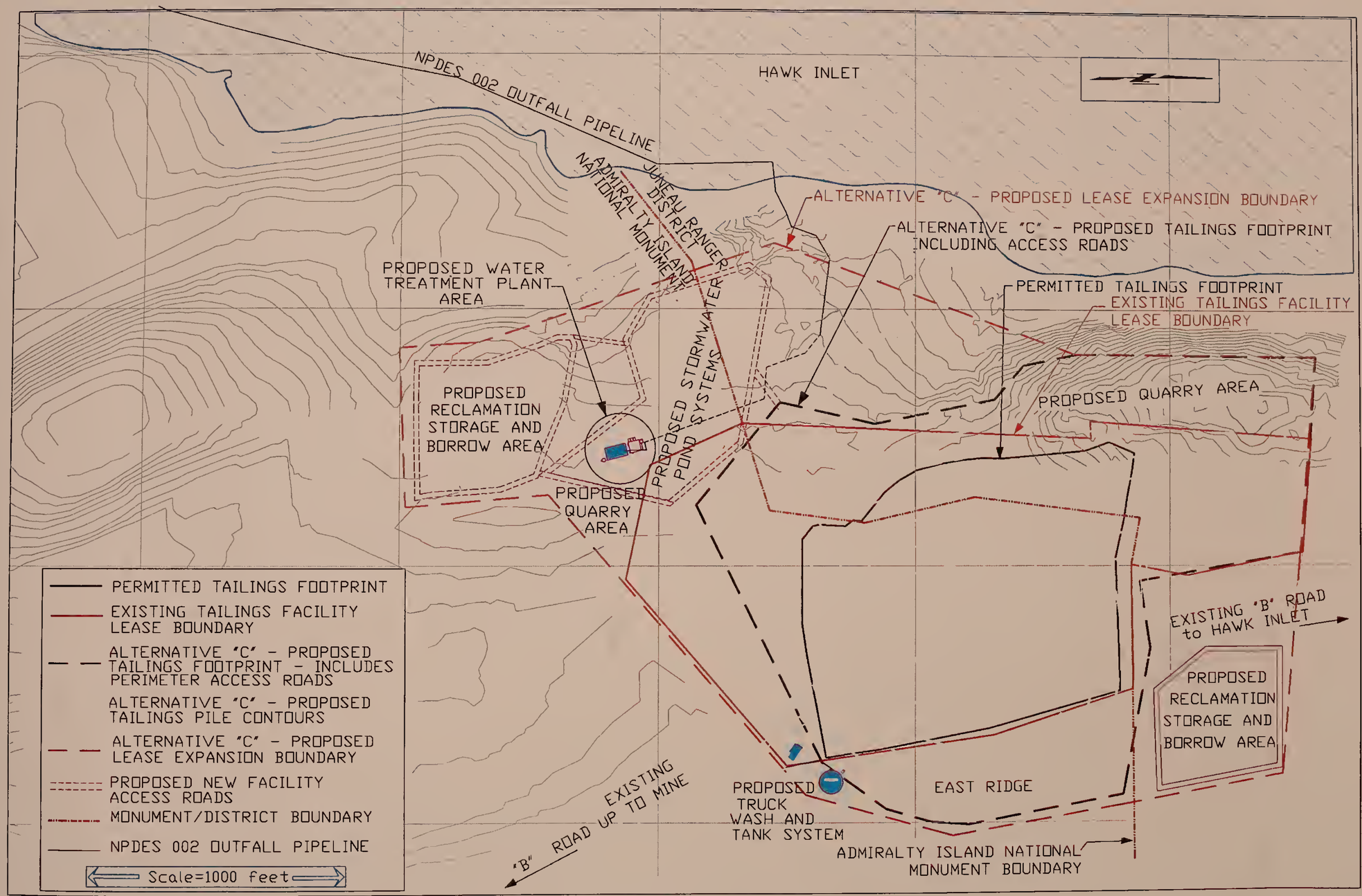
U.S. Environmental Protection Agency
National Pollutant Discharge Elimination System (Section 402 of the Clean Water Act).

State of Alaska, Department of Environmental Conservation
Certification of the COE Section 404 permit
Certification of Section 401 of the EPA NPDES permit
Waste disposal permit for the construction, operation, and maintenance of the tailings disposal facility

State of Alaska, Department of Natural Resources
Approval of the reclamation plan.
Certificate of Approval to construct the dam needed for the storm water runoff pond.

City and Borough of Juneau
Summary approval process or a permit amendment for Large Mine Permit.

Figure 1 Selected Alternative - Existing Tailings Facility Lease Area, Present, and Projected Footprints of Tailings Placement



Reasons for the Decision

In making my decision, I considered all issues and took into account the competing interests and values of the public. Alternative C (East Ridge Expansion) provides the best combination of tailings disposal sites, mitigation measures, and effects on water quality within the framework of existing laws, regulations, policies while meeting the stated purpose and need.

When compared with alternatives B (Proposed Action) and D (Continuous Carbonate Addition), Alternative C will reduce the area disturbed within the Admiralty Island National Monument and provide greater assurance of long-term chemical stability of the tailings while still meeting the direction provided in section 503 of the Alaska National Interest Lands Conservation Act and the Greens Creek Land Exchange Act of 1995.

Alternative C reduces the proposed disturbed area within the Monument by:

1. Eliminating a proposed quarry and associated access roads at the southern end of the lease area.
2. Moving the southern half of the proposed reclamation materials storage area outside of the Monument When compared with Alternatives B and D, this alternative will reduce both the lease area and the disturbed area within the Monument by approximately 22 acres and 47 acres respectively. The net change in lease area will be a decrease of 17.2 acres and 49 acres respectively. Compared with Alternative A, the lease area within the Monument will increase by 30 acres and actual tailings placement will occupy an additional 15.5 acres within the Monument.

Alternative C requires a 30-month study to determine the amount of carbon necessary to ensure continual sulfate reduction throughout the life of the mine and post-closure. Sulfate reduction occurs when organic materials are present. When sulfate is reduced by microorganisms, two by-products, sulfide and bicarbonate are produced. The sulfide ions tend to form insoluble compounds with metals such as zinc and nickel, thereby reducing their concentration in water within the tailings. In addition, bicarbonate tends to increase pH (reducing acidity) which reduces solubility of other metals, especially zinc. Sulfate reduction is a beneficial process to be supported during the life of the mine and after closure. Compared with Alternatives A and B, which have no additional carbon or carbonate added to the tailings, the selected alternative provides greater assurance of long-term chemical stability of the tailings. Compared with Alternative D, which has a continuous addition of carbonate (limestone) to reduce the potential for acid rock drainage, the selected alternative has the additional ability to reduce zinc and selenium occurring in the underdrain water while minimizing the size of the tailings disposal area required.

My decision provides the tailings disposal area necessary for Kennecott Greens Creek Mine to continue operations for the life of the mine based on proven and reasonably foreseeable discoverable reserves of ore. The community of Juneau and other Southeast Alaska communities will benefit from continued mine operation by maintaining 265 direct jobs and 141 indirect jobs. Total annual payroll for the 407 direct and indirect jobs associated with the mine is approximately $38 million. The region will also benefit as the population associated with those jobs (626 people) and school enrollment (125 students) will be maintained. By comparison,

Alternative A (No Action) would result in the loss of jobs, payroll, population, and school enrollment.

In making my decision, I recognize that Alternative A (No Action) would result in mine closure in two years. Alternative B (Proposed Action) and Alternative C (East Ridge Expansion) would allow mine operation an additional 20 years beyond that of Alternative A. Alternative D (Continuous Carbonate Addition) would also allow operations 20 years beyond that of Alternative A. Alternative D, however, increases costs to such an extent that mine operations would be more subject to market fluctuations, increasing the risk of temporary or longer-term shutdown if metal prices were to decline. Alternative C provides a greater degree of stability in employment than does Alternative D.

My decision also affects the City and Borough of Juneau in that annual taxes of $672,000 are assessed on the Kennecott Greens Creek Mine properties. The bulk of that revenue would have been lost had I selected the No Action alternative.

Public Involvement

On March 29, 2001, the Forest Service published a Notice of Intent to prepare an EIS for the proposed project in the Federal Register (Vol. 66, No. 61, Page 17139). Cooperating agencies as defined in 40 CFR, section 1501.6 are the U.S. Army Corps of Engineers and the Environmental Protection Agency. A Memorandum of Understanding was executed that included the following State of Alaska agencies as participants in the development and review of the EIS: Alaska Department of Natural Resources (ADNR), Alaska Department of Environmental Conservation (ADEC), and Alaska Department of Fish and Game (ADF&G). On the date of the notice of intent, the *Kennecott Greens Creek Mine Tailings Disposal Site Environmental Impact Statement Scoping Document, March 2001* was distributed to mandatory mailing lists, environmental groups, and persons who had previously expressed interest in minerals projects on the Tongass. Outreach was conducted with public service announcements in the Juneau Empire and radio media.

On April 19, 2001 a scoping meeting/open house was held in Juneau, Alaska at the City and Borough Assembly chambers, and a second open house on April 23, 2001 in Angoon. The open houses were designed as a means for the project team to provide background information or technical assistance that the public or interested agencies might need before commenting. The scoping document was made available at these meetings. The formal comment period for the initial scoping document ended April 30, 2001.

Using comments from the public, other agencies, and non-governmental organizations several issues regarding the effects of the proposed action were identified (see FEIS pages 1-11 to 1-13). The main issues included:

1. Ensuring the isolation of contact water, generated as a result of continued operations and enlargement of the facility, from groundwater and surface water.
2. Location of the proposed action in and adjacent to the Admiralty Island National Monument.

To address these issues, the Forest Service developed alternatives to the Proposed Action described below.

A Notice of Availability of the Draft EIS was published April 25, 2003 in the Federal Register (Vol. 68, No. 80, Page 20387) and copies of the document distributed to interested and affected parties. A public meeting was held on May 21, 2003 at Centennial Hall in Juneau. The comment period for the Draft EIS closed June 30, 2003. A total of 2,447 comments were received, of which 2,416 were received via e-mail in two different form letter formats.

Alternatives Considered

Four alternatives, including the No Action Alternative, were fully developed and analyzed to address significant issues. Other alternatives were considered, but eliminated from detailed study for various reasons including safety, technical feasibility and the fact that an alternative analyzed in detail better addressed the issues. Pages 2-53 to 2-56 and Appendix G in the EIS describe these alternatives and why they were eliminated from detailed study. The three action alternatives differed from each other in the location of the proposed expansion and the type of treatment used. A more detailed comparison of these alternatives can be found in the EIS on pages 2-41 through 2-52. Alternative A was the environmentally preferred alternative since it would result in no additional disturbance beyond what is currently permitted. The alternatives are summarized as follows:

Alternative A – No Action

Under the "No Action" alternative the existing GPO would not be modified to allow expansion of the tailings disposal facility. KGCMC would continue its present method of generating tailings and would continue to dispose of tailings both as mine backfill and at the currently approved tailings disposal facility. Tailings would be placed at the surface disposal site without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit. The current tailings pile footprint is limited to 29 acres in size with a total lease area of 56 acres including quarries, roads and related facilities.

Alternative B – Proposed Action

Under the Proposed Action alternative the GPO would be modified to allow an increase in the size of the tailings disposal facility to meet the anticipated tailings disposal needs of an additional 22 years of mine operation. As in the No Action Alternative, KGCMC would continue its present method of generating tailings and would continue to dispose of tailings both as mine backfill and at the enlarged surface tailings disposal site without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit. The expanded tailings pile would occupy 61 acres and the total lease area would increase to 140 acres.

Alternative C – Continuous Carbon Addition

See the description of the Selected Alternative above under "Decision".

Alternative D - Continuous Carbonate Addition and Expanded Boundary as needed for Additional Volume

Under Alternative D the GPO would also be modified to allow an increase in the size of the tailings disposal facility to meet the anticipated tailings disposal needs of an additional 22 years of mine operation. As in the No Action Alternative, KGCMC would continue its present method of generating tailings and would continue to dispose of tailings both as mine backfill and at the enlarged surface tailings disposal site. Alternative D would require the continuous addition of

carbonate (limestone) to new tailings placed on the pile as a method of increasing the acid neutralizing potential of the tailings. The volume of carbonate necessary to neutralize the tailings would increase the volume of the pile. The expanded tailings pile would occupy 81 acres and the lease area would increase to 172 acres. A dry storage area for limestone and mixing equipment would be require and would occupy an additional 1 or 2 acres at either the mill or the tailings site.

Comparison of Alternatives

Element	Alternative A	Alternative B	Alternative C	Alternative D
Physical Components				
Tailings Facility Lease Area after expansion (acres)	56	140	123	172
Tailings Facility Lease Area boundaries expansion (acres)	0	84	67	116
Total Tailings Footprint Area (acres)	29	61	62	81
Total Disturbed Area (estimated acres)	54	125	110	162
Tailings Placed Underground				
Tons	0	7,333,000* whole tailings (includes 733,000 cement)	7,333,000* whole tailings (includes 733,000 cement)	7,333,000* whole tailings (includes 733,000 cement)
Cubic Yards	0	4,073,889* (includes 852,326 cement)	4,073,889* (includes 852,326 cement)	4,073,889* (includes 852,326 cement)
Tailings Placed on Surface				
Tons	0	6,000,000* whole tailings	6,000,000* whole tailings	6,000,000* whole tailings
Cubic Yards	0	3,333,333* whole tailings	3,333,333* whole tailings	3,333,333* whole tailings
Amendment Quantity (tons)	0	0*	None to 60,000* carbon	2,034,000* limestone
Amendment Quantity (cu yd)	0	0*	None to 44,776 carbon	1,517,910 limestone
Height of Tailings Pile Above Existing Ground Level (feet)	80	160	160	160
Maximum Tailings Pile Elevation Above Sea Level (feet)	250	330	330	330
Roads				
Miles of New Road	0.16	1.93	1.19	4.30
Miles of Road Obliterated	0.12	0.63	0.94	0.94

Comparison of Alternatives

Element		Alternative A	Alternative B	Alternative C	Alternative D
Total Miles (excluding construction roads on pile)		1.35	2.83	2.82	4.52
Water Treatment Plant Location		Moved	Moved	Moved	Moved
Truck Wash Station Location		Moved	Moved	Moved	Moved
Significant Issues – Water Quality					
Ground Water	w/o treatment	S	S	M	S
	w/ treatment	N	N	N	N
Surface Water	w/o treatment	S	S	M	S
	w/ treatment	N	N	N	N
Marine Waters w/o Mixing Zone	w/o treatment	N	N	N	N
	w/ treatment	N	N	N	N
Marine Waters w/ Mixing Zone	w/o treatment	N	N	N	N
	w/ treatment	N	N	N	N
Significant Issues – Monument Values					
Total Lease Area After Expansion (acres)		56	140	123	172
Lease Boundaries Expansion Area Only (acres)		0	84	67	116
In Monument		38	90	68	115
Outside Of Monument		18	50	55	57
Total Tailings Footprint (approximate acres)					
Total Tailings Footprint Area (acres)		29	61	62	81
In Monument		25	28	36	56
Outside of Monument		4	33	26	25
Other Issues					
Air Quality		N	N	N	N
Visual Quality		M	M	M	M

Comparison of Alternatives

Element	Alternative A	Alternative B	Alternative C	Alternative D
Marine Water Quality	N	N	N	N
Wetlands Impacts – (Though acreage of filled wetlands differs, all are evaluated as minor in the context of the project and study area)	M 0 ac. beyond those already permitted	M 22 ac. Low Value	M 10 ac. Low Value	M 42 ac Low Value / 0.7 ac. Medium Value
Vegetation	M	M 71 ac.	M 56 ac.	M 108 ac.
Wildlife				
Terrestrial Mammals	N	N	N	N
Birds	N	N	N	N
Marine Mammals	None	None	None	None
T&E Species	None	None	None	None
Marine Life	N	N	N	N
Essential Fish Habitat	N	N	N	N
Heritage Resources	None	None	None	None
Subsistence	N	N	N	N
Recreation	N	N	N	N
Socioeconomic	M adverse	M positive	M positive	M adverse
Estimated Cost of Construction and Implementation	$ 0 ***	$ 10,000,000 – $ 20,000,000	$ 11,000,000 – $ 26,000,000	$ 75,000,000 – $ 280,000,000
Environmental Justice	None	None	None	None
Cumulative Impacts	N	N	N	N

Weight / Volume Conversions: cement = .86 t/yd^3, limestone/carbon = 1.34 t/yd^3
Whole Tailings = 1.8 t/yd^3
* Weights and volumes indicate value above currently permitted amount (2.1M yd^3, 3.78 M t.)
** Estimated placement volumes based on currently permitted volumes at tailings
*** Baseline for comparison of estimated increased costs
S = Significant, M = Minor, N = Negligible

Planning Record

The planning record for this project includes the Draft EIS, Final EIS, appendices, public comments, response to public comments, Forest Plan, all material incorporated by reference, and all materials utilized during the analysis of this project. The planning record is available at the Juneau Ranger District office.

Findings Required by Law

Tongass Land and Resource Management Plan, 1997

All project alternatives are consistent with the 1997 Tongass Forest Plan. The site is located within an area designated as Nonwilderness National Monument with a Minerals prescription. This decision to allow expansion of the existing tailings facility as described in Alternative C is consistent with the intent of the forest plan's long term goals and objectives listed on pages 2-2 to 2-6. The project was designed in conformance with forest plan standards and incorporates appropriate Forest Plan guidelines for Nonwilderness National Monument with a Minerals prescription (Forest Plan, pages 3-41 to 3-49 and 3-151 to 3-157).

Alaska National Interest Lands Conservation Act (ANILCA)

An ANILCA Section 810 subsistence evaluation was conducted. There will not be a significant possibility of a significant restriction on the abundance and distribution of, access to, or competition for subsistence resources in the project area.

Endangered Species Act

Consultations with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service have been conducted, and these agencies have concurred that the proposed project is not likely to affect any threatened or endangered species. A complete biological assessment is included in the planning record.

Essential Fish Habitat

The potential effects of the Greens Creek Tailings Disposal project on essential fish habitat (EFH) have been evaluated. The risk of measurable impact on essential fish habitat has been minimized in the project area. I have determined that this project may adversely affect essential fish habitat. I plan to continue working with the National Marine Fisheries Service in evaluating monitoring results. For specific information regarding essential fish habitat and potential impacts refer to the EFH Assessment located in the Project Planning Record and pages 3-101 to 3-116 and 4-46 to 4-47.

National Historic Preservation Act

Cultural resource surveys of varying intensities have been conducted in the project area, following inventory protocols approved by the Alaska State Historic Preservation Officer. Tribal entities, village and regional corporations have been consulted and public comment encouraged. The Section 106 Review process has resulted in a determination of "No Historic Properties affected" as detailed in the 2nd Amended Regional Programmatic Agreement (#02 MU-111001-076).

Coastal Zone Management Act
The Coastal Zone Management Act (CZMA) requires that the Forest Service, when conducting or authorizing activities or development be consistent with the approved Alaska Coastal Management Program (ACMP) to the maximum extent practicable. This activity is one authorized under a Forest Service permit, as defined in 15 CFR 930.51(a). The Forest Service/State of Alaska Memorandum of Understanding on Coastal Zone Management Act/Alaska Coastal Management Program Consistency Reviews (MOU) lists permitted activities normally requiring a consistency determination (MOU, Section 302.B.2.). This activity is listed in Section 302.B.2 as normally requiring a consistency determination. A Coastal Project Questionnaire has been completed by KGCMC, and submitted to the State of Alaska for their consistency determination. A consistency determination will be received before the permit is issued.

Executive Orders

Executive Order 11988 (Floodplain Management)
This area is not located within floodplains as defined by executive order 11988.

Executive Order 11990 (Protection of Wetlands)
Because wetlands are so extensive in the Greens Creek Tailings Disposal project area, it is not feasible to avoid all wetland areas. I have determined that (1) there is no practicable alternative to such construction and (2) the selected alternative includes all practicable measures to minimize harm to wetlands which may result from such use. A separate permit will be issued for wetland fill activities by the US Army Corps of Engineers.

Executive Order 12898 (Environmental Justice)
Implementation of this decision will not result in disproportionate adverse human health or environmental effects to minority or low-income populations.

Executive Order 12962 (Recreational Fisheries)
With the application of Forest Plan standards and guidelines, including those for riparian areas, no significant adverse effects to freshwater or marine resources will occur. Most recreational fishing throughout the Tongass occurs by boat in saltwater, and any adverse effects would be minimal.

Executive Order 13186 (Migratory Birds)
Implementation of this decision will not have any significant adverse effects to migratory birds and their habitat.

Implementation of this Decision

Implementation of this decision may occur no sooner than 50 days from the date of publication of the notice of this decision in the *Juneau Empire*, the official newspaper of record.

Right to Appeal

This decision is subject to administrative review (appeal) pursuant to 36 CFR part 215. The appeal filing period closes 45 days after the publication of legal notice of this decision in the *Juneau Empire* newspaper, published in Juneau, Alaska. A written notice of appeal must be filed with the Appeal Deciding Officer:

Denny Bschor, Regional Forester
USDA Forest Service, Region 10
P.O. Box 021628
Juneau, AK 99802-1628

In accordance with 36 CFR part 215.14, it is the responsibility of those who appeal a decision to provide the Appeal Decision Officer sufficient evidence and rationale to show why the Responsible Official's decision should be remanded or reversed. The written notice of appeal filed must meet the following requirements:

1. State the document is a Notice of Appeal filed pursuant to 36 CFR part 215;
2. List the name, address, and telephone number of appellant;
3. Identify the decision document by title and subject, date of the decision, and name and Identify the specific change(s) in the decision that the appellant seeks or portion of the decision to which the appellant objects;
4. State how the Responsible Official's decision fails to consider comments previously provided, either before or during the comment period specified in 36 CFR 215.6 and, if applicable, how the appellant believes the decision violates law, regulation, or policy.

Contact Person
For additional information concerning this decision or the Forest Service appeal process, contact

Pete Griffin
Juneau District Ranger
8465 Old Dairy Road
Juneau, Alaska 99801
(907) 586-8800

Forrest Cole

FORREST COLE
Forest Supervisor

10/24/03
[DATE]

Greens Creek Tailings Disposal

Final Environmental Impact Statement

Tongass National Forest
USDA Forest Service, Alaska

Lead Federal Agency	USDA Forest Service Tongass National Forest
Responsible Official	Forrest Cole, Forest Supervisor Tongass National Forest Supervisors Office 648 Mission St. Ketchikan, Alaska 99901-6591
Cooperating Agencies:	U.S. Army Corps of Engineers U.S. Environmental Protection Agency
With assistance from:	Michael Baker Jr., Inc.
For Further Information Contact:	Jeffrey Wade DeFreest Minerals Program Manager Tongass National Forest Juneau Ranger District 8465 Old Dairy Road Juneau AK 99801 Phone: 907-790-7457 E-mail: jdefreest@fs.fed.us

Abstract

The USDA Forest Service is proposing to approve a modification to the KGCMC General Plan of Operation to authorize the expansion of the tailings disposal area at the Greens Creek Mine to accommodate continued processing of known and projected ore reserves. Water quality and monument values were identified as significant issues and these issues, as well as other important concerns, are addressed by the alternatives in this Environmental Impact Statement (EIS). This EIS describes the effects of the No-Action alternative, the Proposed Action, and two other action alternatives.

No appropriated funds were used in the publishing of this EIS. The funds for research for this EIS were provided by the Kennecott Greens Creek Mining Company with the approval of the Forest Service.

Table of Contents

APPENDICIES – in Volume II

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Figures – Volume I

Tables – Volume I

Executive Summary

Table of Contents – Executive Summary

Tables

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Executive Summary

Final Environmental Impact Statement

Greens Creek Tailings Disposal

Background

The Greens Creek Mine is an underground metals mine near Hawk Inlet on northern Admiralty Island. It is located approximately 18 miles southwest of Juneau, Alaska. The mine is situated in the Greens Creek watershed within the Admiralty Island National Monument. In 1980, Congress provided for mining at the Greens Creek site in Section 503 of the Alaska Native Interest Land Conservation Act (ANILCA).

Before mining operations began, the United States Department of Agriculture, Forest Service, published the Greens Creek Final Environmental Impact Statement (USDA, FS 1983) and issued its Record of Decision (ROD) for overall development and operation of the mine project. In early 1984, the Forest Service approved a General Plan of Operations (GPO) for Noranda Mining, Inc., the owner and operator at that time.

That original GPO called for underground mining with ore crushed and concentrated in a mill near the mine portal. Under the plan, the ore concentrate was to be trucked approximately nine miles to the Hawk Inlet port at the Cannery; from there, it was to be shipped to smelters outside Alaska for processing and refining. The *tailings*—the material left after the minerals have been removed—was to be placed in a *slurry*, or watery mixture, and piped along the road corridor to a site at the Cannery Muskeg for disposal.

While planning was still going on, ownership of the mine changed hands, and in early 1986, Amselco assumed control of operations. The new owner decided to change some aspects of the GPO, particularly the method of tailings disposal. Instead of putting tailings in slurry, Amselco proposed to truck dry tailings to a smaller area at the same Cannery Muskeg for disposal. In July 1987, the Forest Service determined that this and other proposed changes to the GPO required a National Environmental Policy Act (NEPA) review. The following year, the Forest Service published the *Environmental Assessment for Proposed Changes to the General Plan of Operations for the Development and Operation of the Greens Creek Mine* (USDA, FS 1988).

Full-scale development of the mine began in 1987. Workers excavating for the mill site found a large, unanticipated volume of porous soil that had to be removed in order to provide a suitable foundation for the mill. Because this soil was placed in the mine's approved waste rock disposal site, higher volumes of waste rock than anticipated were disposed of at the tailings site,

which decreased available capacity for tailings. Also, ongoing exploration had identified additional ore reserves.

In response to these changed circumstances, in 1990 the project's operator, now Kennecott Greens Creek Mining Company (KGCMC - the applicant), sought approval for additional waste rock disposal capacity. As a result, in 1991 the Forest Service began a third NEPA review and the following year published the *Environmental Assessment for Additional Waste Rock Disposal Capacity at Greens Creek Mine* (USDA, FS 1992).

In April of 1993, KGCMC temporarily suspended mining operations due to depressed prices for metals. In 1995, Congress passed the Greens Creek Land Exchange Act, which granted Greens Creek subsurface rights to 7,500 acres of land immediately adjacent to its patented claims in exchange for 139 acres of private inholdings in the Admiralty Island National Monument and 50 acres of private inholdings in Misty Fiords National Monument. Upon completion of mining, the exchanged 7,500 acres, as well as all lands currently owned or yet to be acquired by Kennecott on Admiralty Island, will, after reclamation, revert to the United States and be included in the Admiralty Island National Monument, Tongass National Forest.

KGCMC reopened the project in July of 1996, and in conjunction with the resumption of mining operations, the Forest Service approved an amendment to the GPO. Prior to closure in 1993, KGCMC experienced several violations of Alaska Water Quality Standards (AWQS). Upon reopening in 1997, KGCMC attempted to use an ozone treatment for its domestic wastewater discharge. The system didn't function properly and led to several exceedances of permit limits relating to domestic wastewater discharge, though no fines were imposed.

The Greens Creek Mine supports an annual payroll of approximately $26 million and employs a workforce of approximately 265 individuals—120 in mining and underground support, 60 in the mill, 55 in surface support, and 30 in administration. KGCMC presently processes in excess of 2,000 tons of ore per day. On an annual basis, that production yields approximately 10 million ounces of silver, 65,000 ounces of gold, and a total of 200,000 tons of zinc, lead, and bulk concentrates.

Based on known ore reserves and the current rate of production, the Greens Creek Mine has a remaining life of approximately 12 years (from 2003). KGCMC expects to backfill approximately half the tailings underground and use surface disposal at rates averaging up to 270,000 tons per year. At that rate, surface disposal capacity for approximately 3 ½ million tons of tailings will be needed during the remaining 12-year life of the mine. Under the current permit, however, the existing tailings facility has space for only about 600,000 tons of tailings— roughly 2 years of tailings disposal at the current

level of production. Consequently, an additional disposal capacity of 2 ½ million tons is needed to process the known ore reserves.

In addition to the known ore reserves, past success in exploring indicates the likelihood that geologists may discover new deposits in the area. KGCMC has indicated that such discoveries could mean that mine life would extend an additional 10 years and surface disposal space would be needed for at least another 3 million tons of tailings. Thus, based on known and anticipated ore reserves and the current rate of tailings placement, KGCMC expects a mine life of 22 years which would require site capacity for 5½ to 6 million tons of tailings on surface disposal.

Based on the need for additional surface disposal, in January 2001, KGCMC submitted an application to the Forest Service requesting a modification of the existing GPO for expansion of both the area and the disposal capacity of the existing tailings facility. The Greens Creek application described alternatives that would meet KGCMC's need while satisfying its regulatory obligations, and identified their formal proposal.

The Forest Service and cooperating agencies reviewed the KGCMC proposal and its possible effects. Based on this review, the Forest Service developed a Proposed Action to carry forward, and determined the appropriate level of analysis given the impacts the proposed action might have on the environment.

In March 2001, the Forest Service issued a Notice of Intent to prepare an Environmental Impact Statement (EIS) to analyze and display the effects of proposed changes to the tailings operations. The Forest Service determined that the proposed project warranted an EIS because an expansion of the tailings disposal facility could significantly impact such things as water quality, wetlands, fisheries, and the values inherent in the Admiralty Island National Monument.

In the process of preparing the analysis, the Forest Service encouraged public comment, and based on the input, the Forest Service identified *significant issues*—those issues that present such potential for impact to the environment that they must be given special consideration. Through the consideration of these significant issues, the Forest Service formulated alternatives to the proposed action, including a *no action* alternative.

This summary briefly describes the primary contents of the Final EIS as follows:

- Chapter 1, Purpose of and Need for Action—Describes the Proposed Action-based on project revisions submitted by the operator and the purpose and need for the Proposed Action; discusses the need for preparation of the EIS and issuance of other Federal, State, and local

permits; and identifies issues raised during the scoping process and addressed by this analysis.

- Chapter 2, Description of Alternatives, Including No Action, and the Proposed Action—Describes how the alternatives were developed, describes the Proposed Action and compares the alternatives.

- Chapter 3, Affected Environment—Provides information on the physical and biological environment and socioeconomic conditions that would be affected by the alternatives.

- Chapter 4, Environmental Consequences—Describes the potential environmental consequences of all alternatives.

This summary provides an overview of the Final EIS, including important information from Chapters 1 through 4 and the appendices. Beyond the information in this FEIS, additional documentation of the environmental analysis is contained in the planning record, which is available to the public at the Juneau Ranger District Office.

S.1 Purpose of and Need for Proposed Action

"The purpose and need for the proposed action is to consider changes to the 2000 approved Plan of Operations (as amended) for the Kennecott Greens Creek Mining Company regarding tailings disposal in order to allow for continued operations."

The Forest Supervisor of the Tongass National Forest is the Responsible Official for this decision. The Forest Supervisor will document the decision based on the analysis provided in the Final EIS. He may select one of the alternatives discussed herein, select an alternative that combines components of more than one alternative, or select an alternative that includes additional mitigation measures. As a cooperating agency, the Corps of Engineers will adopt this Final EIS and issue its own ROD in conjunction with its permits for the Greens Creek Mine Tailings Expansion. The Environmental Protection Agency (EPA) will utilize the information in this EIS in issuing its National Pollutant Discharge Elimination System (NPDES) permit for the Greens Creek Mine.

As required by regulations implementing the National Environmental Policy Act, the Forest Service conducted a thorough scoping process that encouraged public, agency, and tribal participation in regular meetings (40 CFR 1501.7). The process involved, among other things, examining the proposed action and its possible effects, identifying issues of concern related to the project, and determining which require detailed study.

On March 29, 2001, the Forest Service published its notice of intent to prepare an EIS for the proposed project in the *Federal Register* (USDA, FS 2001a), and distributed a scoping document describing the proposed action, the EIS process, and a schedule for the preparation of documents. (*Scoping Document for Greens Creek Mine Tailings Stage II Expansion Project Environmental Impact Statement,* USDA, FS 2001b). The project name has been shortened to "Greens Creek Tailings Disposal".

Distribution of the scoping document began a 30-day period for the public and interested agencies to review the document and to comment. Comments were solicited from the general public, state and federal agencies, tribes, municipal governments, and other interested parties. On April 19th, the Forest Service hosted a scoping open house in Juneau and on April 23rd in Angoon. The comment period ran until April 30, 2001.

During the scoping process, the Forest Service identified issues that are significant to the given project.

Issue 1. The Forest Service identified water quality as the first significant issue for the proposed Greens Creek project.

"Ensuring the isolation of contact water generated as a result of continued operations and enlargement of the facility from groundwater and surface waters. In the short term, this isolation will be achieved through diversion, integrity of sub layers, lining where appropriate, and treatment. In the long term, this isolation will be achieved through diversion, integrity of sub layers and liners where placed, and capping.

Water quality concerns raised during scoping included:

- ***The potential for metals loading and /or acid rock drainage (ARD) from the tailings pile.***
- ***The need for reduction of contaminants in the pile.***
- ***The long-term, post closure, maintenance of surface and groundwater standards.***
- ***The effectiveness of proposed methods for controlling water that does not come in contact with the pile.***
- ***The need to add a monitoring program to measure metals uptake by wetland communities.***
- ***The potential to increase in-stream sediments and bioaccumulation of metals in plants and animals.***

These water quality issues may require the formulation of major mitigation actions connected to the Proposed Action or consideration of an alternative."

This issue is particularly important because when water comes in contact with tailings, the quality of that water can be impaired. The process of sulfide oxidation and the short- and long term geochemistry of tailings are discussed in detail in Chapter 3. Tailings associated with this project contain an abundance of pyrite (iron sulfide), a mineral that is not removed as ore concentrate during processing. If exposed to air and water, pyrite slowly weathers, creating heat and sulfuric acid. The acid created when pyrite weathers may be consumed by dolomite contained in the tailings, but the metals and sulfate contained in the pile become soluble, and are more likely to dissolve into any water they contact. If this happens, the quality of that water degrades, and, if the water is not contained, treated or diluted, the environment for plant, fish, and wildlife may also be impaired. Consequently, minimizing the contact of air with tailings and isolating them from water is critical. Tailings disposal and tailings storage, therefore, must minimize contact with water.

Issue 2. Consideration of the values inherent in the Admiralty Island National Monument was identified as the second significant issue connected to the proposed project.

"Location of the proposed action in and adjacent to the Admiralty Island National Monument must be considered. Impacts to the Monument are considered because part of the proposed action would occur within the National Monument. Consideration of this issue may require the formulation of an alternative in which the footprint of the proposed development is altered to minimize impacts within the Monument boundaries."

The Admiralty Island National Monument was established in 1978 by Presidential Proclamation 43.[1] Although "Monument values" were defined in neither the Presidential Proclamation nor the Alaska National Interest Lands Conservation Act (ANILCA), they were addressed in the context of the Forest Service's 1983 and 1988 NEPA reviews of the Greens Creek Mine lease and operations.

Both the EIS (in 1983) and the EA (in 1988) evaluated proposal alternatives against the following two considerations:

- Keeping intact, to the maximum extent feasible, the system of resource values by using non-Monument lands; and
- The potential for reclamation of impacted areas to pre-project conditions.

1 Federal Register 57009 - December 1, 1978.

Section 503 of ANILCA provides that, "with respect to the mineral deposits at Greens Creek, the holders of valid mining claims … shall be entitled to a lease (and necessary associated permits) on lands under the Secretary's Jurisdiction …. for use for mining or milling purposes … from such claims situated within the Monuments," provided "that the use of the site to be leased will not cause irreparable harm to the … Admiralty Island National Monument and … the Secretary shall limit the size of the area covered by such lease …"

Other issues were identified during the scoping process as important, but not significant enough to require the development of alternative actions. They are described as follows:

- The tailing facility design must be adequate. The design of the proposed tailings facility, including the engineering standards to be incorporated should be discussed as well as the adequacy of those standards.
- The cumulative impacts from extended mine operation and those from other projects in the area should be considered.
- Impacts to wetlands should be considered.
- Direct and cumulative impacts to fish and wildlife resources should be considered among the alternatives. Mitigation measures to reduce impacts should be described.
- Socioeconomic impacts should be considered and analyzed for all alternatives.

While these issues are not considered "significant" for the purpose of this analysis they are discussed in Chapters 3 and 4.

S.2 Description of Alternatives, including the Proposed Action

Under the National Environmental Policy Act (NEPA), the consideration of the significant issues leads to the formulation of various alternatives to a proposed action, as well as to the design of mitigation measures when needed.

Elements common to all alternatives

There are a number of elements that are common to all alternatives including the No Action alternative. These items are described below.

- All discharged water will meet Alaska Water Quality Standards (AWQS).
- No new roads outside of the tailings lease area will be constructed (Roads will be constructed within the lease area

atop the slurry walls, on the pile itself, and to pile facilities within the disturbed area of the pile lease area.

- The characteristics of the tailings, prior to the addition of any additives, are the same.
- A final 3H:1V (3 horizontal to 1 vertical) outer slope would be used for all tailings piles.
- The water treatment plant will be relocated.
- An engineered 4-layer soil cap would be placed over the pile after closure to minimize the infiltration of oxygen and water. The design (see Chapter 2, Figure 2-3) would be approved by the Forest Service and DEC.
- During operation and for a period of years afterwards until discharges can meet AWQS without treatment, all water that comes into contact with the tailings along with other industrial waste water would be contained, collected and actively treated. Details of the water treatment process are described below.
- If upward groundwater gradients are not sufficient to provide containment of contact water, the facility design in the expansion area would also utilize a liner system to prevent discharge of tailings water into groundwater beneath the tailings.
- During mine closure and post-closure periods, water would continue to be treated until effluent quality is such that these treatment processes are not required in order to meet discharge requirements. At that time and depending on actual effluent quality, KGCMC would discharge water using one of these discharge/compliance scenarios, in decreasing order of preference. Diagrams of these scenarios are shown in Chapter 2, Figure 2-1:

  (1) Discharge into nearby surface or groundwater (a) without dilution water from pile runoff and groundwater, or (b) with such dilution. This discharge would meet fresh water quality-based effluent limits;

  (2) Discharge directly into Hawk Inlet. This discharge would meet marine water quality–based effluent limits with a potential dilution factor from a mixing zone; or

  (3) Continue to discharge into Hawk Inlet through a submerged diffuser. The effluent would meet the more stringent of either marine AWQS with a mixing zone or technology based limits.

The decision as to which scenario would be utilized and when it would be implemented during the closure and post-closure period would be proposed by KGCMC to the regulatory agencies per the requirements set forth in the GPO (KGCMC, 2001c). Once the agencies have confirmed through monitoring that the treatment plant is no longer required, it would be removed and the site reclaimed to return the area to generally natural conditions (KGCMC, 2001c).

Any of these discharge/compliance scenarios would be conducted under a re-issued NPDES permit with any pertinent mixing zone authorized by ADEC. Figure 2-9, Chapter 2 summarizes the discharge decision logic used to determine which discharge scenario to use during the closure and post-closure period.

For all action alternatives:

- The tailings placement footprint is designed to provide tailings storage for the anticipated remaining 22 year life of the mine (approximately 12 years at present rate of production for known reserves and 10 years for potentially developing undiscovered reserves).
- The finished height of the pile would be approximately 160 feet above ground level (330 feet above sea level). Its existing height is 80 feet above ground level.
- Placement of tailings could necessitate the relocation of the water treatment plant and a portion of the mine access road. Other than the relocation of this portion of the road, no new road construction is associated with any alternative.
- A Design Basis Earthquake (DBE) for operations (Crustal Earthquake –1/475 year, M6.5) and a Maximum Design Earthquake (MDE) for closure design (equal to 75% of Maximum Credible Earthquake, M7.0).
- Interception and diversion systems to control non-contact water around the treatment facility, as similar systems currently function.
- Approved containment structures (such as liners where appropriate, slurry walls, and low-permeability deposits, as are now in use) to protect both groundwater and adjacent surface water.
- Water would continue to be treated at a water treatment plant as described under Alternative A.
- The Pit 5 water treatment plant would be moved to a new location within the expanded lease area.

- Construction of a new water management pond system designed for a 25-year, 24-hour runoff event. The ponds would utilize a low-permeability liner as used in the existing stormwater ponds. Installation of surface water and groundwater controls and diversions.
- Drainage infrastructure sufficient to meet geotechnical requirements to minimize phreatic levels within the tailings pile.

Alternative A – No Action

The "No Action" alternative would not modify the existing GPO nor permit expansion of the tailings disposal facility beyond its currently permitted size. The tailings lease area is 56 acres. The tailings footprint would expand from its current size of 23 acres to the currently permitted 29 acres.

KGCMC would continue its present method of generating whole tailings. The tailings would be placed without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit. Under the current permit the existing tailings facility has space for about 600,000 additional tons of tailings. Without a permitted expansion of the tailings pile, the mine would run out of room for surface disposal of tailings in roughly 2 years of tailings disposal at the current level of production.

Alternative B – Proposed Action

Alternative B, the Proposed Action, would modify the GPO to permit an increase in the size of the tailings pile, primarily to the west and the south. The tailings lease area would be 140 acres and the tailings footprint would be 61 acres. KGCMC would continue its present method of generating whole tailings. The tailings would be placed without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit.

Alternative C – East Ridge Expansion

Alternative C differs from the Proposed Action in two substantive ways. Alternative C would modify the GPO to permit expansion of the existing tailings disposal facility to the east of the present location, but would eliminate a proposed quarry and associated access roads at the southern end of the lease area and move the southern half of the proposed reclamation materials storage area outside of the Monument to the northeast corner just outside the current lease area. The combination of these actions would decrease the lease area and disturbed area in Admiralty Island National Monument. This scenario would also increase the geotechnical stability of the pile by using natural topographic features as a buttress for the pile. The

tailings lease area would be 123 acres and the tailings footprint would be 62 acres.

The second difference is the approach to managing water quality. Sulfate reduction is currently occurring within the pile and has beneficial effects on improving effluent quality. Carbon is currently present in the tailings from mill floatation reagents and dewatering flocculants and biosolids from the Cannery wastewater treatment.

A sulfate reduction monitoring plan (SRMP) will identify the optimum placement method, quantity and type of carbon required to assure a sulfate reducing environment following closure of the mine which may eliminate the need for chemical/physical water treatment after mine closure. In other words, the SRMP would be implemented to 1) determine the effectiveness of the current level of carbon addition and its adequacy in maintaining a reducing environment in the pile during operations; 2) identify the quantity of carbon required to assure a reducing environment following closure of the mine and thus eliminate the need for chemical/physical water treatment after mine closure; 3) determine the need for supplemental carbon addition to ensure that sulfate reduction processes continue in order to meet water quality standards. The SRMP would be completed and its findings submitted to the regulatory agencies for approval within 30 months of the issuance of the ROD, and after approval, would be specified in the GPO.

Alternative D – Continuous Carbonate Addition and Expanded Boundary as needed for Additional Volume

The purpose of this alternative is to increase the neutralizing potential of the tailings pile beyond what is expected in the proposed action. Alternative D would require mixing carbonate (in the form of limestone) into the tailings on an on-going basis, either in the mill or in the process of putting the tailings on the pile. The addition of the carbonate would increase the buffering capacity of the pile, or its ability to neutralize acid. Avoidance of acidification through buffering would provide some deterrence to metals leaching, but not as effectively as Alternative C. About 2 million tons, or 1½ million cubic yards, of limestone would be needed to sufficiently neutralize the tailings.

The addition of limestone would increase the volume of the pile and require expanding the tailings facility lease area. The tailings lease area would be 172 acres and the tailings footprint would be 81 acres. The method of tailings placement and pile height would be the same as Alternatives B and C.

This alternative would also require a structure of about 18,000 square feet for dry storage of limestone, and equipment for mixing the limestone into the tailings. In addition to the increase of the size of the tailings pile, the dry

storage area for limestone and mixing equipment would require an additional 1to 2 acre increase in the footprint at the mill or tailings site.

S.3 Comparison of Alternatives

The EIS compares the alternatives based on their impacts on water quality, monument values, and other issues identified during scoping. To the extent possible, the environmental consequences are quantified and objectively described. This section compares the impacts in summary form.

The terms *significant, minor,* and *negligible,* are used in the comparisons and in Chapter 4. These terms are explained in the introduction of Chapter 4 and in the glossary. The thresholds for what represents a negligible, minor, or significant impact differ for each resource. For example, significance of water quality impacts is determined by comparison to AWQS; significance of impacts to wetlands is evaluated by the area of low, medium, or high value wetlands that would be filled. Two alternatives can have different levels of consequence, for example differing levels of wetlands filled, but still both be evaluated as having minor levels of impacts in the context of the project and study area.

able S-1 Comparison of Alternatives

Element	Alternative A	Alternative B	Alternative C	Alternative D
Physical Components				
Tailings Facility Lease Area after expansion (acres)	56	140	123	172
Tailings Facility Lease Area boundaries expansion (acres)	0	84	67	116
Total Tailings Footprint Area (acres)	29	61	62	81
Total Disturbed Area (estimated acres)	54	125	110	162
Tailings Placed Underground				
Tons	0	7,333,000* whole tailings (includes 733,000 cement)	7,333,000* whole tailings (includes 733,000 cement)	7,333,000* whole tailings (includes 733,000 cement)
Cubic Yards	0	4,073,889* (includes 852,326 cement)	4,073,889* (includes 852,326 cement)	4,073,889* (includes 852,326 cement)
Tailings Placed on Surface				
Tons	0	6,000,000* whole tailings	6,000,000* whole tailings	6,000,000* whole tailings
Cubic Yards	0	3,333,333* whole tailings	3,333,333* whole tailings	3,333,333* whole tailings
Amendment Quantity (tons)	0	0*	None to 60,000* carbon	2,034,000* limestone
Amendment Quantity (cu yd)	0	0*	None to 44,776 carbon	1,517,910 limestone
Height of Tailings Pile Above Existing Ground Level (feet)	80	160	160	160
Maximum Tailings Pile Elevation Above Sea Level (feet)	250	330	330	330
Roads				
Miles of New Road	0.16	1.93	1.19	4.30
Miles of Road Obliterated	0.12	0.63	0.94	0.94

'able S-1 Comparison of Alternatives

Element		Alternative A	Alternative B	Alternative C	Alternative D
Total Miles (excluding construction roads on pile)		1.35	2.83	2.82	4.52
Water Treatment Plant Location		Moved	Moved	Moved	Moved
Truck Wash Station Location		Moved	Moved	Moved	Moved
Significant Issues – Water Quality					
Ground Water	w/o treatment	S	S	M	S
	w/ treatment	N	N	N	N
Surface Water	w/o treatment	S	S	M	S
	w/ treatment	N	N	N	N
Marine Waters w/o Mixing Zone	w/o treatment	N	N	N	N
	w/ treatment	N	N	N	N
Marine Waters w/ Mixing Zone	w/o treatment	N	N	N	N
	w/ treatment	N	N	N	N
Significant Issues – Monument Values					
Total Lease Area After Expansion (acres)		56	140	123	172
Lease Boundaries Expansion Area Only (acres)		0	84	67	116
In Monument		38	90	68	115
Outside Of Monument		18	50	55	57
Total Tailings Footprint (approximate acres)					
Total Tailings Footprint Area (acres)		29	61	62	81
In Monument		25	28	36	56
Outside of Monument		4	33	26	25
Other Issues					
Air Quality		N	N	N	N
Visual Quality		M	M	M	M

'able S-1 Comparison of Alternatives

Element	Alternative A	Alternative B	Alternative C	Alternative D
Marine Water Quality	N	N	N	N
Wetlands Impacts – (Though acreage of filled wetlands differs, all are evaluated as minor in the context of the project and study area)	M 0 ac. beyond those already permitted	M 22 ac. Low Value	M 10 ac. Low Value	M 42 ac Low Value / 0.7 ac. Medium Value
Vegetation	M	M 71 ac.	M 56 ac.	M 108 ac.
Wildlife				
Terrestrial Mammals	N	N	N	N
Birds	N	N	N	N
Marine Mammals	None	None	None	None
T&E Species	None	None	None	None
Marine Life	N	N	N	N
Essential Fish Habitat	N	N	N	N
Heritage Resources	None	None	None	None
Subsistence	N	N	N	N
Recreation	N	N	N	N
Socioeconomic	M adverse	M positive	M positive	M adverse
Estimated Cost of Construction and Implementation	$ 0 ***	$ 10,000,000 – $ 20,000,000	$ 11,000,000 – $ 26,000,000	$ 75,000,000 – $ 280,000,000
Environmental Justice	None	None	None	None
Cumulative Impacts	N	N	N	N

Weight / Volume Conversions: cement = .86 t/yd^3, limestone/carbon = 1.34 t/yd^3
Whole Tailings = 1.8 t/yd^3
* Weights and volumes indicate value above currently permitted amount (2.1M yd^3, 3.78 M t.)
** Estimated placement volumes based on currently permitted volumes at tailings
*** Baseline for comparison of estimated increased costs
S = Significant, M = Minor, N = Negligible

Water Quality

Alaska Water Quality Standards (AWQS) were revised on June 26, 2003. Overall, the direction of the revisions made the standards relevant to Greens Creek more stringent. The analysis of water quality in this FEIS is based on the new standards and some impact analyses have changed. As discussed above under elements common to all alternatives, water in exceedance of NPDES limits and AWQS will not be discharged. During mine closure and post-closure periods, water will continue to be treated using approved treatment processes until effluent quality is such that treatment processes are not required in order to meet discharge requirements. At that time and depending on actual effluent quality, KGCMC would discharge water according to the hierarchy of discharge scenarios/compliance points described above in Elements common to all alternatives. The stochastic water quality model, described in Appendix A, predicts the quality of the water draining from the pile over time without the use of existing treatment processes, beginning at the onset of closure (completion of the cap). Water quality for each alternative is discussed below. Table S-1 above displays the effects related to water quality for each alternative under the various compliance point scenarios.

Alternative A

All discharged water will meet Alaska Water Quality Standards (AWQS). Results from the water quality model for Alternative A indicate that exceedances to fresh water AWQS for sulfate and antimony are initially predicted for underdrain water. Between 5 and 25 years, antimony levels should drop below AWQS, but selenium may increase and could exceed AWQS. After 200 years, sulfate should have declined below AWQS, but zinc is predicted to have risen above AWQS. After 500 years, cadmium is predicted to be above AWQS. None of these substances exceeds AWQS initially at the compliance point where underdrain flow mixes with surface water and groundwater, but selenium, zinc and cadmium may exceed AWQS at the compliance point after 100, 350 and 1000 years, respectively (without treatment). Selenium should have returned to concentrations below AWQS after 350 years. The predicted increase in downgradient concentrations of selenium, zinc and cadmium may impair existing protected water use classes.

Model results compared to AWQS for marine water are the same as compared to fresh water standards, with the exception of sulfate, as there is no marine standard for sulfate. The predicted load of metals was compared to the currently allowable loads under the NPDES marine discharge permit for the facility. Predicted loads were less than one percent of allowable loads for Alternative A for all metals in the permit.

Effects to water quality in the Hawk Inlet drainage would be considered *significant* if tailings effluent is discharged (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be *negligible* adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be *negligible* adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be *negligible* adverse effects to receiving surface water, groundwater or marine water.

Alternative B

All discharged water will meet Alaska Water Quality Standards (AWQS). Results from the water quality model are similar to those for Alternative A, indicating that sulfate and antimony would initially exceed fresh water AWQS in the underdrain flow from beneath the tailings pile. After 25 to 100 years, selenium, zinc and cadmium may be above AWQS (without treatment). After 350 years, sulfate and antimony should have decreased below fresh water AWQS. At the compliance point, only sulfate would initially exceed fresh water AWQS, but selenium, zinc and cadmium are expected to exceed fresh water AWQS at the compliance point after 25, 200 and 500 years respectively without treatment. The predicted increase in downgradient concentrations of selenium, zinc and cadmium may impair existing protected water use classes.

Model results for Alternative B compared to AWQS for marine water are the same as compared to fresh water standards, with the exception of sulfate, as there is no marine standard for sulfate. The predicted load of metals was compared to the currently allowable loads under the NPDES marine discharge permit for the facility. Predicted loads were less than 2 percent of allowable loads for Alternative B for all metals in the permit.

Like Alternative A, effects to water quality in the Hawk Inlet drainage would be considered significant if tailings effluent is discharged (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be *negligible* adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater or marine water.

Alternative C

All discharged water will meet Alaska Water Quality Standards (AWQS). Results from the water quality model for Alternative C reflect the fundamental difference in long-term chemistry that would result from the addition of carbon to the tailings pile. As with Alternatives A and B, initially water in the underdrains could exceed fresh water AWQS for sulfate and antimony. Sulfate concentrations are expected to have decreased to below fresh water AWQS after 350 years. Elevated zinc and selenium would not occur in the underdrain water because on-going sulfate reduction tends to remove these constituents. Antimony, on the other hand, is not affected by sulfate reduction, and may increase as a result of biological reduction. The elevated antimony that are predicted by the model are likely to be removed from solution when the water from the underdrain contacts air causing iron and manganese compounds to chemically precipitate, adsorb antimony, and settle from solution. All of these substances are expected to meet fresh water AWQS except for sulfate, which is marginally above fresh water AWQS at the compliance point for the first 50 to 100 years (without treatment).

Results of the water quality model for Alternative C compared to marine water AWQS are the same as compared to fresh water AWQS, with the exception of sulfate, as there is no marine standard for sulfate. The predicted load of metals was compared to the loads currently allowable under the NPDES marine discharge permit for the facility. Predicted loads were less than 0.1 percent of allowable loads for Alternative C for all metals in the permit.

Effects to water quality in the Hawk Inlet drainage are considered *minor* (compared to *significant* for Alternatives A and B) for the case where tailings effluent is discharged directly (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to receiving waters (discharge scenario 1). If water treatment were continued in perpetuity, there would be negligible adverse effects to the receiving surface water or groundwater. There would be negligible adverse effects to marine water for the case where tailings effluent is discharged directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects for the case where tailings effluent is discharged through a diffuser into Hawk Inlet (discharge scenario 3).

Alternative D

All discharged water will meet Alaska Water Quality Standards (AWQS). Water quality for Alternative D is similar to that of Alternative B, with concentrations of sulfate and metals slightly higher due to the greater area of the pile. In the underdrain (without dilution, discharge scenario 1(a)), sulfate and antimony may initially exceed AWQS followed by AWQS exceedances of selenium, zinc, and cadmium after 25, 50, and 100 years, respectively.

At the compliance point with dilution (discharge scenario 1(b)), sulfate and antimony initially exceed AWQS, but are predicted to be below AWQS after 200 and 25 years, respectively. Selenium, zinc, and cadmium are predicted to be above AWQS after 25, 200, and 500 years, respectively. These predicted exceedances of AWQS under discharge/compliance scenario 1 would impair existing protected water use classes if discharged without treatment. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Results of the water quality model for Alternative D compared to marine water AWQS (discharge scenario 2) show there are no exceedances. The predicted load of metals was compared to the loads currently allowable under the NPDES discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than 2 percent of allowable loads for Alternative D for all metals in the permit.

As with Alternatives A and B, effects to water quality in the Hawk Inlet drainage are considered *significant* for the case where tailings effluent is discharged directly (without treatment) to surface water or groundwater without dilution, or with dilution (without treatment) with surface water or groundwater prior to discharge to receiving waters (discharge/compliance scenario 1). Effects to marine water would be *negligible*, the same as Alternative A, B, C for the case where effluent is discharged directly to Hawk Inlet (without treatment or diffuser) (discharge/compliance scenario 2). There would be *negligible* adverse effects for the case where tailings effluent is discharged through a diffuser into Hawk Inlet (discharge/compliance scenario 3) - the same as under Alternatives A, B, and C. If water treatment were continued in perpetuity, there would be *negligible* adverse effects to receiving surface water, groundwater, or marine water.

Monument Values

The main criterion for comparing effects to Monument values is the numbers of acres leased within the Monument and subject to potential disturbance. Alternative A would result in a lease of 38 acres in the Monument. The tailings footprint within the Monument currently occupies 20 acres and would ultimately increase to 25 acres as permitted in the GPO. Alternative B would result in a lease of 90 acres in the Monument with the tailings footprint occupying 28 of those acres. Alternative C would result in a lease of 68 acres in the Monument with the tailings footprint occupying 36 of those acres. Alternative D would result in a lease of 115 acres in the Monument with the tailings facility occupying 56 of those acres. Table S-1 presents a comparison of acreages.

Other Issues

While the effects of each alternative on other resources or issues varied, most fell within the same range. For example the difference between the action alternatives effect on wetlands ranged from fill in 10 acres of low value wetlands for Alternative C to fill in 42 acres of low value wetlands and less than 1 acre of medium value wetlands for Alternative D. In the context of the study area, however, the impacts of all alternatives on wetlands are minor.

None of the alternatives have any impact on marine mammals, Threatened and Endangered species, or heritage resources. The impacts of all alternatives on air quality, marine water quality, terrestrial mammals, birds, subsistence and recreation are negligible. The impacts of all alternatives are minor for visual quality, wetlands, vegetation, and Essential Fish Habitat. Alternatives A and D have a minor adverse impact on socioeconomics and Alternatives B and C have a minor positive impact on socioeconomics and environmental justice. All alternatives will have cumulative impacts. See Table S-1.

S.4 Appendices and Planning Record

The appendices provide additional information as part of the FEIS. They are listed below with brief descriptions or notes.

Appendix A – Michael Baker Jr., Inc. 2003. Hydrology and Geochemistry of the Greens Creek Tailings Facility. April.

Appendix B – Sulfate Reduction Monitoring Program Outline, 2002

> The issues of geochemistry and hydrology in this FEIS are complex and a reading of Appendix A, Hydrology and Geochemistry of the Greens Creek Tailings Facility and Appendix B, Sulfate Reduction Monitoring Program Outline will contribute to an in-depth understanding of the issue.

Appendix C – Selected Appendices from KGCMC General Plan of Operation

- KGCMC. 2000, August. General Plan of Operations, Appendix 3 – Tailings Impoundment.
- KGCMC. 2000, October. General Plan of Operations, Appendix 14 - Reclamation Plan.

Appendix D – ADEC Waste Management Permit, 2003

> Reading Appendices C, Selected Appendices from KGCM General Plan of Operation, and D, ADEC Waste Management Permit, will give readers a better understanding of the conditions and requirements that Greens Creek operates under.

Appendix E – Response to Draft EIS Comments, 2003

Appendix F –Draft EIS Comments, 2003

Appendices E and F will allow readers to see the questions and comments reviewers offered on the DEIS.

Appendix G – Alternative Screening Evaluation, 2002

Appendix G is the document that was developed when examining alternatives to be considered in this EIS. Included in this document are in-depth considerations of various pyrite circuit alternatives that some commenters had suggested during scoping.

Planning Record – Beyond the information in this FEIS, additional documentation of the environmental analysis, including the Jurisdiction Wetlands Survey and Sensitive Plant Survey, is contained in the planning record, which is available to the public at the Juneau Ranger District Office, 8465 Old Dairy Rd., Juneau, AK, 99803, 907-586-8800.

Chapter 1
Purpose and Need for Proposed Action

1 Purpose and Need for Proposed Action

Background

The Greens Creek Mine is an underground metals mine near Hawk Inlet on northern Admiralty Island. It is located approximately 18 miles southwest of Juneau, Alaska. The mine is situated in the Greens Creek watershed within the Admiralty Island National Monument.

Before mining operations began, the United States Department of Agriculture, Forest Service, published the *Greens Creek Final Environmental Impact Statement* (USDA, FS 1983) and issued its Record of Decision (ROD) for overall development and operation of the mine project. In early 1984, the Forest Service approved a General Plan of Operations for Noranda Mining, Inc., the owner and operator at that time.

That original General Plan of Operations (GPO) called for underground mining with ore crushed and concentrated in a mill near the mine portal. Under the plan, the ore concentrate would be trucked approximately nine miles to the Hawk Inlet port at the Cannery; from there, it would be shipped to smelters outside Alaska for processing and refining. The *tailings*—the material left after the minerals have been removed—would be placed in a *slurry*, or watery mixture, and piped along the road corridor to a site at the Cannery Muskeg for disposal.

While planning was still going on, ownership of the mine changed hands, and in early 1986, Amselco assumed control of operations. The new owner decided to change some aspects of the GPO, particularly the method of tailings disposal. Instead of putting tailings in a slurry, Amselco proposed to truck dry tailings to a smaller area at the same Cannery Muskeg for disposal. In July 1987, the Forest Service determined that this and other proposed changes required a National Environmental Policy Act (NEPA) review. The following year, the Forest Service published the *Environmental Assessment for Proposed Changes to the General Plan of Operations for the Development and Operation of the Greens Creek Mine* (USDA, FS 1988).

Full-scale development of the mine began in 1987. Workers excavating for the mill site found a large, unanticipated volume of porous soil that had to be removed in order to provide a suitable foundation for the mill. Because this soil was placed in the mine's approved waste rock disposal site, more waste rock had to go to the tailings facility, thereby reducing capacity available for tails. Also, ongoing exploration had identified additional ore reserves.

In response to these changed circumstances, in 1990 the project's operator, now Kennecott Greens Creek Mining Company (KGCMC - the current operator), sought approval for additional waste rock disposal capacity. In 1991 the Forest Service began a third NEPA review and the following year

published the *Environmental Assessment for Additional Waste Rock Disposal Capacity at Greens Creek Mine* (USDA, FS 1992).

In April of 1993, KGCMC temporarily suspended mining operations due to depressed prices for metals. KGCMC reopened the project in July of 1996, and in conjunction with the resumption of mining operations, the Forest Service approved an amendment to the GPO.

The Greens Creek Mine supports an annual payroll of approximately $26 million and employs a workforce of approximately 265 individuals—120 in mining and underground support, 60 in the mill, 55 in surface support, and 30 in administration. KGCMC presently processes approximately 2,000 tons of ore per day. On an annual basis, that production yields approximately 10 million ounces of silver, 65,000 ounces of gold, and a total of 200,000 tons of zinc and lead bulk concentrates.

Based on known ore reserves and the current rate of production, the Greens Creek Mine has a remaining life of approximately 12 years (from 2003). KGCMC expects to backfill approximately half the tailings and use surface disposal at an average rate of 270,000 tons per year. At that rate, surface disposal capacity for approximately 3.2 million tons of tailings will be needed during the remaining 12-year life of the mine. Under the current permit, however, the existing tailings facility has space for only about 600,000 tons of tailings— just over 2 years of tailings disposal at the current level of production. Consequently, to process the known ore reserves, additional disposal capacity of approximately 2½ million tons is needed.

In addition to the known ore reserves, past success in exploring indicates the probability that geologists may discover new deposits in the area. KGCMC has indicated that such discoveries could mean that mine life would extend an additional 10 years and surface disposal space would be needed for at least another 3 million tons of tailings. Thus, based on known and anticipated ore reserves and the current rate of tailings placement, KGCMC expects a mine life of 22 years and site capacity for roughly 6 million tons of additional tailings.

Based on that need, in January 2001, KGCMC submitted an application to the Forest Service requesting a modification of the existing GPO for expansion of both the area and the disposal capacity of the existing tailings facility. The Greens Creek application described alternatives that would meet KGCMC's need while satisfying its regulatory obligations, and identified their formal proposal.

The Forest Service and cooperating agencies reviewed the KGCMC proposal and its possible effects. Based on this review, the Forest Service developed a Proposed Action to carry forward. The team also determined the appropriate

type of analysis given the impacts the proposed action might have on the environment.

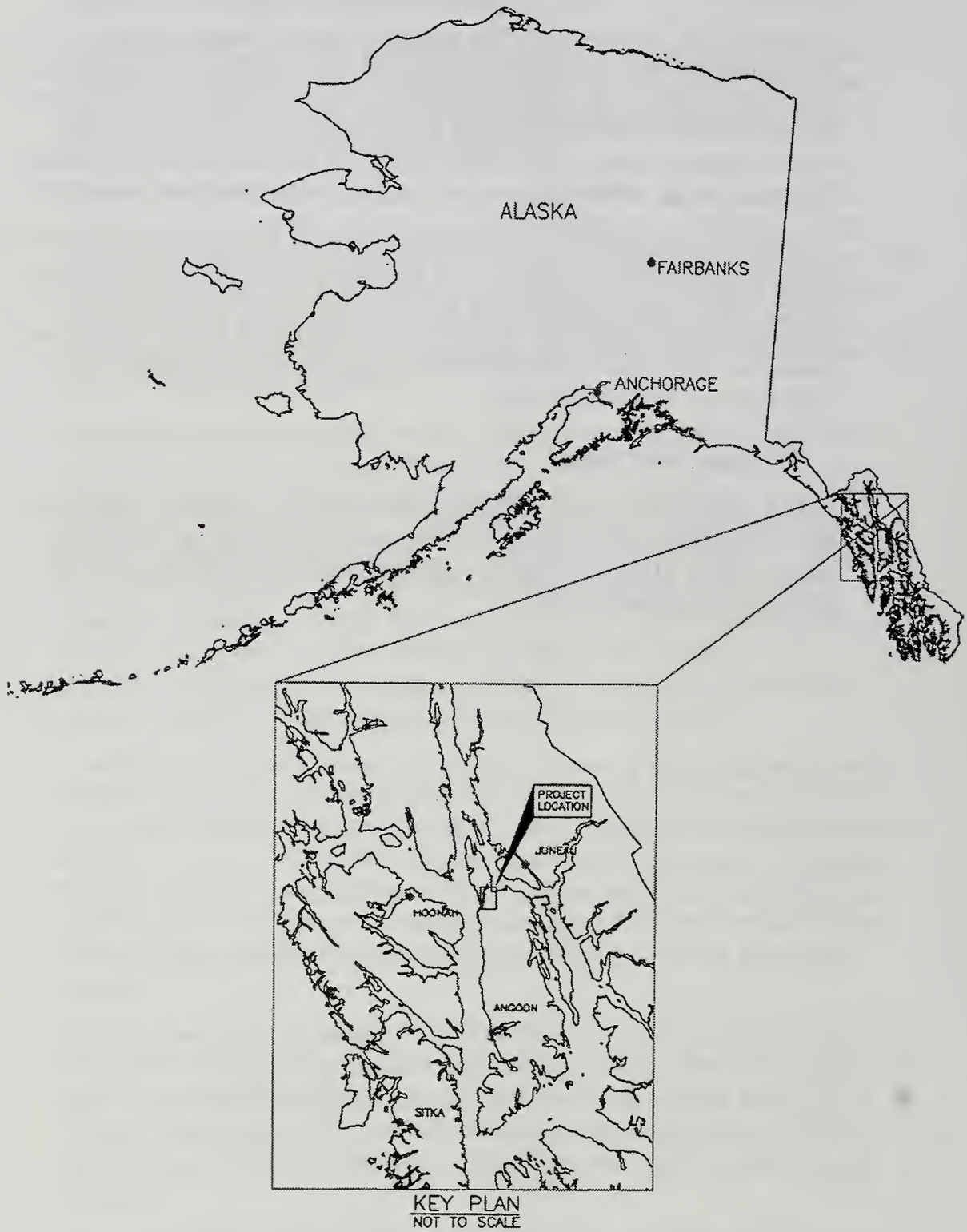
In March 2001, the Forest Service issued a Notice of Intent to prepare an Environmental Impact Statement (EIS) to analyze and display the effects of proposed changes to the tailings operations. The Forest Service determined that the proposed project warranted an EIS because an expansion of the tailings disposal facility could significantly impact water quality, wetlands, fisheries, and the values inherent to Admiralty Island National Monument.

In the process of preparing the analysis, the Forest Service encouraged public comment, and based on the input, the Forest Service identified *significant issues*—those issues related to the proposed action that identify potential impacts to the environment. Through the consideration of these significant issues, the Forest Service formulated alternatives to the proposed action, including a *no action* alternative.

Purpose and Need

"The purpose and need for the proposed action is to consider changes to the 2000 approved Plan of Operations (as amended) for the Kennecott Greens Creek Mining Company regarding tailings disposal in order to allow for continued operations."

Figure 1-1 Project Location

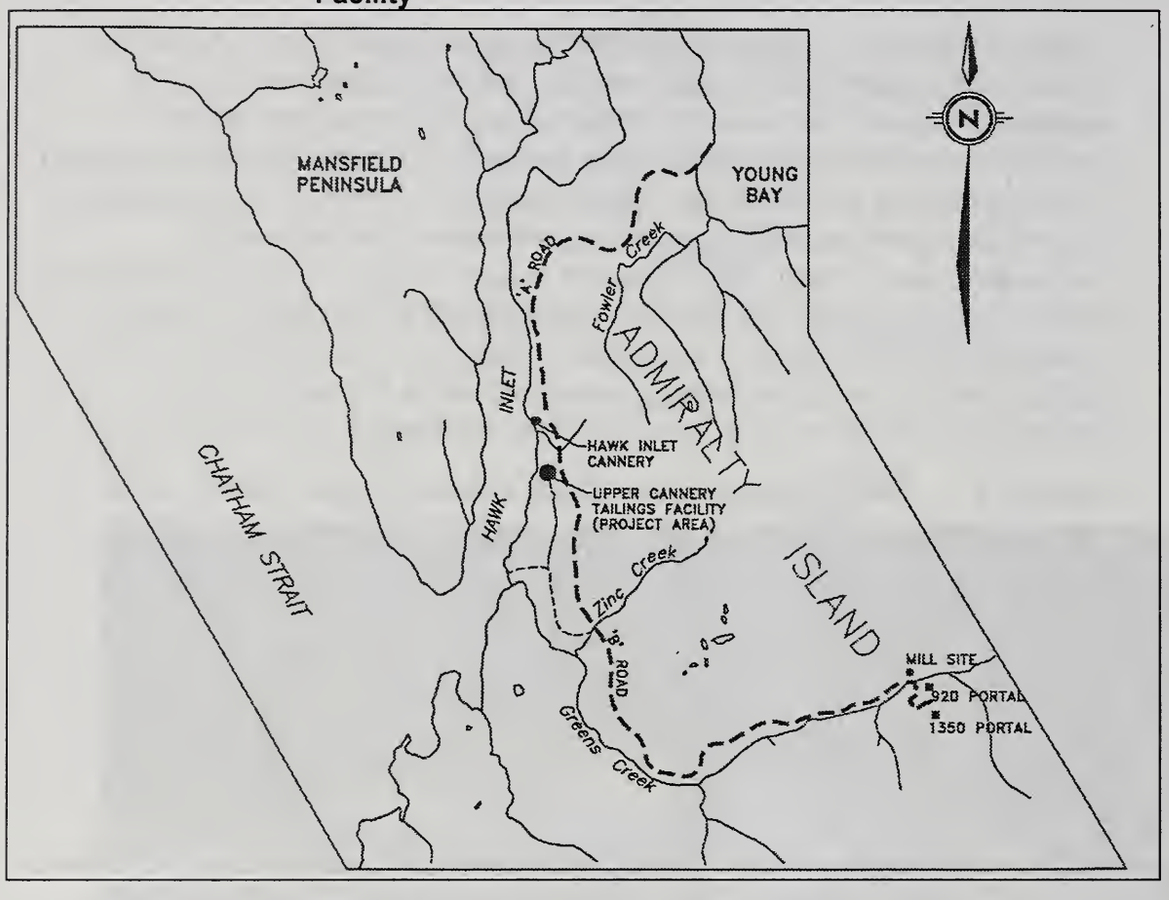


1.1 Proposed Action

The Forest Service proposes to approve an amendment to the KGCMC GPO to authorize construction of additional dry tailings disposal storage. The additional disposal area would be designed to provide enough disposal capacity (approximately 6 million tons above the currently permitted capacity) for the remaining life of the mine (approximately 22 years at the present rate of production and backfilling, given known reserves and reasonably foreseeable discoveries). This expansion would require modifying the existing lease. Figure 1-2 shows the Greens Creek existing tailings facility and the mine project area; Figure 1-3 shows the location of the tailings facility. The tailings pile, including the tailings expansion area is in a semi-remote recreation LUD and is not in an inventoried roadless area (See Figure 3-2).

Figure 1-2 Aerial View of Greens Creek Existing Tailings Facility (2002)

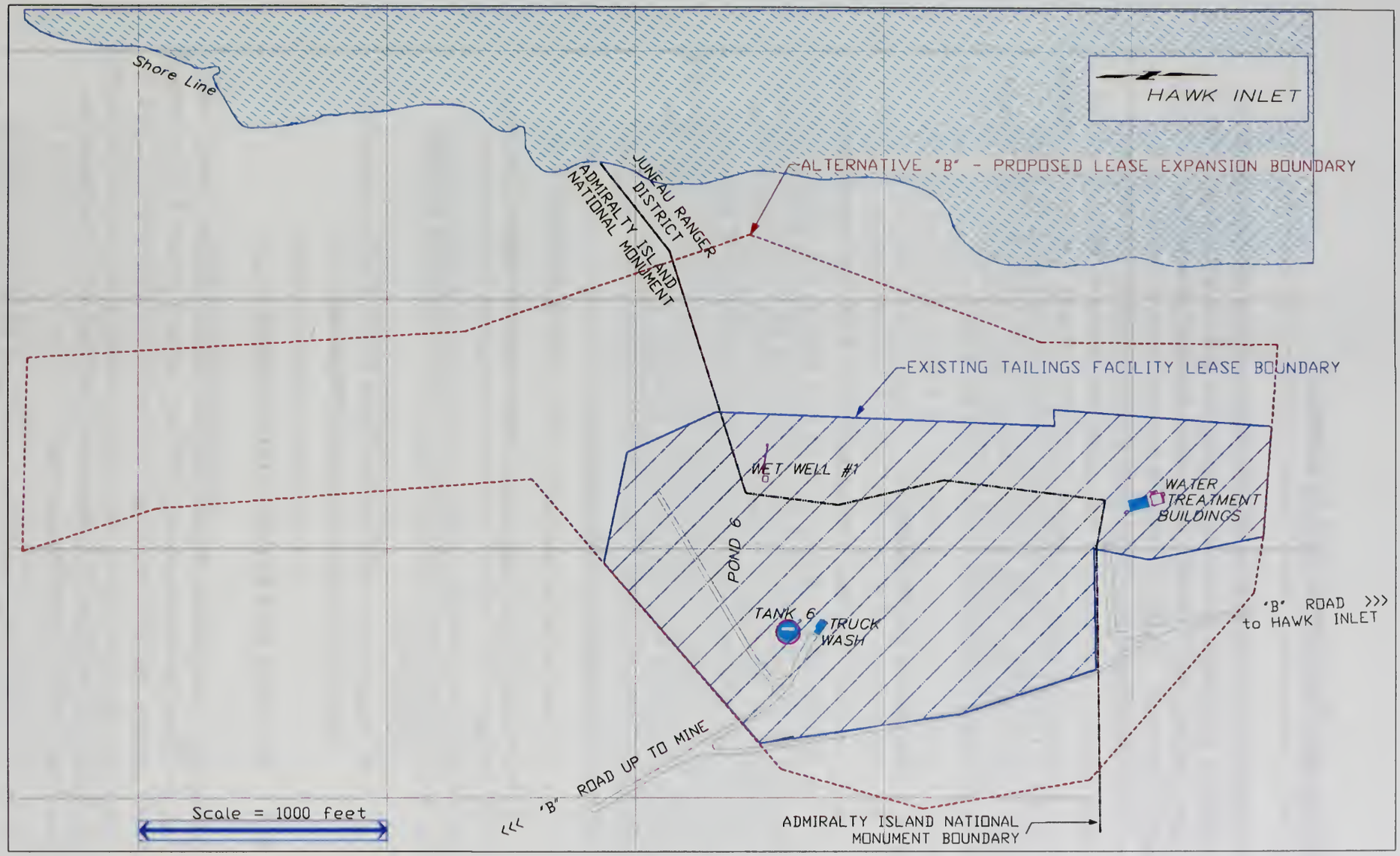
Figure 1-3 Greens Creek Mine Project Area and Location of Existing Tailings Facility



The lease area for the existing tailings facility is 56 acres. The proposed action would expand the area by 84 acres, primarily to the west and south, for a new total of about 140 acres. Tailings disposal would occur on about 40 acres within the new area; the remaining 44 acres would be used for rock quarries, a stormwater pond system, and storage area for reclamation materials, as well as a possible new water treatment plant and other potential long-term tailings disposal needs. Figure 1-4 shows the existing 56-acre tailings facility lease area and associated facilities, as well as the proposed new 84-acre expansion area.

Before the proposed expansion could begin, the existing reclamation plan (GPO Appendix 14) would be updated to reflect new downgradient compliance locations for the re-configured tailings pile used for compliance monitoring for water quality. The Forest Service and other agencies with permitting jurisdiction would approve the updated plan. The GPO includes a requirement that AWQS will be achieved at the points of compliance.

Figure 1-4 Existing Tailings Facility Lease and Alternative B Proposed Expanded Lease Areas



An engineered cover would be placed over the tailings pile to minimize air and water infiltration after closure, as required in the Alaska Department of Conservation (ADEC) Waste Management Permit (Appendix D). The final *lift*, or placement, of tailings would be covered with a series of organic materials including a layer of compacted barrier material and a layer of growth media. These materials that make up the cover would be layered in such a way as to include a sequence of *capillary breaks*. Capillary breaks are created by layers of rock through which water can drain from the layers above. The small gaps between the rocks also keep water within the tailings from wicking up through the cover by capillary action.

1.2 Decision to be Made

Although several federal and state agencies have a role in the environmental analysis process, the Forest Service is the lead agency. The USDA Forest Service is proposing to approve a modification to the KGCMC General Plan of Operation to authorize the expansion of the tailings disposal area at the Greens Creek Mine to accommodate continued processing of known and projected ore reserves. The Forest Supervisor will document the decision in a Record of Decision based on the analysis presented in the Final EIS. The Forest Supervisor will make one of the following decisions:

- Select the No Action alternative; or
- Select an action alternative without modification; or
- Select project components of more than one action alternative; or
- Select an action alternative and require additional mitigation measures; or
- Select project components of more than one action alternative and require additional mitigation measures.

1.3 Scoping and Public Involvement

As required by regulations implementing the National Environmental Policy Act, the Forest Service conducted a thorough scoping process that encouraged public, agency, and tribal participation in regular meetings (40 CFR 1501.7). The process involved, among other things, examining the proposed action and its possible effects, identifying issues of concern related to the project, and determining which require detailed study.

On March 29, 2001, the Forest Service published its Notice of Intent to prepare an EIS for the proposed project in the Federal Register (USDA, FS

2001a) and distributed a scoping document describing the proposed action, the EIS process, and a schedule for the preparation of documents. (Scoping Document for Greens Creek Mine Tailings Stage II Expansion Project Environmental Impact Statement, USDA, FS 2001b). The name of this project was subsequently shortened to Creek Mine Tailings Disposal Final Environmental Impact Statement

Distribution of the scoping document began a 30-day period for the public and interested agencies to review the document and to comment. Comments were solicited from the general public, state and federal agencies, tribes, and municipal governments. On April 19, 2001 the Forest Service hosted a scoping open house at the City and Borough of Juneau Assembly chambers. Thirty-six individuals signed-in, and an estimated ten more came but did not sign-in. Approximately a dozen people attended a second open house in Angoon on April 23. The comment period ended April 30.

These scoping open houses served two purposes. The first was for representatives of the Forest Service and other cooperating agencies to listen to and record public comments about the proposed project as described in the scoping document. The second purpose was for the project team to respond to requests for background information or technical assistance that the public or interested agencies might need before commenting. Both open houses were held early in the comment period so that people who had questions would still have time to prepare and submit their comments before the close of the comment period.

Agency representatives documented, as part of the official record, all comments made during the open houses, whether oral or written. The Forest Service collected 58 sets of oral or written comments containing a total of 135 individual comments. The commenting group can be categorized as follows.

Individual members of the public	44
Municipal government	1
Non-government organizations	6
Businesses	2
State and federal agencies	5
Total	**58**

The Greens Creek Tailings Disposal DEIS was distributed on April 25, 2003. A public meeting was held in Juneau at Centennial Hall on May 21, 2003, for both the Draft EIS and the Alaska Department of Environmental Conservation (ADEC) Waste Management Permit. The comment period ended on June 30,

2003. Comments were solicited from the general public, state and federal agencies, tribes, municipal governments, and non-profit/governmental organizations during the comment period. All comments received during the comment period, whether written in letters, electronic mail or comments taken at the Draft EIS public meeting were read and categorized into the issues discussed below.

A total of 2447 commenters submitted written comment statements in response to the Draft EIS, of those 2416 were received via email in two separate form letters. See Form Letter A (FLA) and Form Letter B (FLB) in Appendix F. 1305 copies of FLA were received (one hard copy was received by mail); 55 of the FLA letters contained additional comments, revisions, or commentary. 1112 copies of FLB were received and 26 of those contained additional comments, revisions, or commentary, one hard copy was also received by mail. Many commenters raised several issues, and each issue was considered individually. A breakdown by general commenting group is shown below.

Individual members of the public		2437
(Form Letter A -	1305)	
(Form Letter B -	1112)	
(Other letters or written comments -	20)	
Non-government organizations		4
Businesses		3
Federal Agencies		3
Total		**2447**

1.4 Significant Issues

During the scoping process, the Forest Service identified issues that are significant to the given project. It is the consideration of the significant issues that leads to the formulation of various alternatives to a proposed action, as well as to the design of mitigation measures when needed. The Forest Service identified water quality and monument values as significant issues connected to the proposed project. These issues were defined as:

Issue 1. Water Quality

"Ensuring the isolation of contact water generated as a result of continued operations and enlargement of the facility from groundwater and surface waters. In the short term, this isolation will be achieved through diversion, integrity of sub layers, lining where appropriate, and treatment. In the long term, this isolation will be achieved through diversion, integrity of sub layers and liners where placed, and capping.

Water quality concerns raised during scoping included:

- ***The potential for metals loading and /or acid rock drainage (ARD) from the tailings pile.***
- ***The need for reduction of contaminants in the pile.***
- ***The long-term, post closure, maintenance of surface and groundwater standards.***
- ***The effectiveness of proposed methods for controlling water that does not come in contact with the pile.***
- ***The need to add a monitoring program to measure metals uptake by wetland communities.***
- ***The potential to increase in-stream sediments and bioaccumulation of metals in plants and animals.***

These water quality issues may require the formulation of major mitigation actions connected to the Proposed Action or consideration of an alternative."

When water comes in contact with tailings, the quality of that water can be impaired. The process of sulfide oxidation and the short- and long term geochemistry of tailings are discussed in detail in Chapter 3. Tailings associated with this project contain an abundance of pyrite (iron sulfide), a mineral that is not removed as ore concentrate during processing. If exposed to air and water, pyrite weathers, creating heat and sulfuric acid. The acid created when pyrite weathers may be consumed by dolomite contained in the tailings, but the metals and sulfate contained in the pile become soluble, and are more likely to dissolve into any water they contact. If this happens, the quality of the contact water degrades, and, if the water is not contained, treated or diluted, the environment for plant, fish, and wildlife may also be impaired. Consequently, minimizing the contact of air with tailings and isolating them from water is critical. Tailings disposal and tailings storage, therefore, must minimize contact with air and water.

Issue 2. Admiralty Island National Monument Values

"Location of the proposed action in and adjacent to the Admiralty Island National Monument must be considered. Impacts to the Monument are considered because part of the proposed action would occur within the National Monument. Consideration of this issue may require the formulation of an alternative in which the footprint of the proposed development is altered to minimize impacts within the Monument boundaries."

The Admiralty Island National Monument was established in 1978 by Presidential Proclamation 43.[1] Although "Monument values" were defined in neither the Presidential Proclamation nor the Alaska National Interest Lands Conservation Act (ANILCA), they were addressed in the context of the Forest Service's 1983 and 1988 NEPA reviews of the Greens Creek Mine lease and operations.

Both the EIS (in 1983) and the EA (in 1988) evaluated proposal alternatives against the following two considerations:

- Keeping intact, to the maximum extent feasible, the system of resource values by using non-Monument lands; and
- The potential for reclamation of impacted areas to pre-project conditions.

Federal regulations address mining operations within the Monument and identify those "resource values" that should be protected as "resources of ecological, heritage, geological, historical, prehistorical, and scientific interest likely to be affected by the proposed operations, including access."[2]

A proposed action must include all feasible measures which are necessary to prevent or minimize potential adverse impacts on the resource values. Determining the *feasibility* of mitigating measures involves balancing the effectiveness and practicality of those measures for preventing or minimizing potential adverse impacts against the short- and long-term costs to the operator and the effect of those costs on the short- and long-term economic viability of the operations.[3]

1.5 Other Issues

"Other issues" were identified during the scoping process as important, but not significant enough to require the development of alternative actions. While these issues are not considered "significant" for the purpose of this analysis they are discussed in Chapters 3 and 4. They are described as follows:

- The tailing facility design must be adequate. The design of the proposed tailings facility, including the engineering standards

1 Federal Register 57009 - December 1, 1978.
2 "Operations within Misty Fjords and Admiralty Island National Monuments, Alaska," 36 CFR § 228.80(b)(1).
3 36 CFR § 228.80(c).

to be incorporated should be discussed as well as the adequacy of those standards.

- The cumulative impacts from extended mine operation and those from other projects in the area should be considered.
- Impacts to wetlands should be considered.
- Direct and cumulative impacts to fish and wildlife resources should be considered among the alternatives. Mitigation measures to reduce impacts should be described.
- Socioeconomic impacts should be considered and analyzed for all alternatives.

1.6 Agency Responsibilities (Permits and Approvals)

The Forest Service, as the lead agency, cooperates and consults with other agencies in regard to the proposed action and the alternative actions that have been developed in response to the significant issues. Each agency evaluates the alternatives for their potential impacts in relation to that agency's own particular area of expertise and jurisdiction.

Listed below are the applicable Laws, Statutes and Ordinances as well as Permits and Decisions as they apply to the proposed Greens Creek tailings expansion.

Laws, Statutes and Ordinances

- Migratory Bird Conservation Act 1929
- Fish and Wildlife Coordination Act 1934 (FWCA)
- Bald and Golden Eagle Protection Act 1940
- Clean Water Act 1948 (CWA)
- Clean Air Act 1955 (CAA)
- National Historic Preservation Act 1966 (NHPA)
- National Environmental Policy Act 1969 (NEPA)
- Marine Mammal Protection Act 1972 (MMPA)
- General Mining Law of 1872
- Coastal Zone Management Act 1972, (as amended) (CZMA)
- Magnuson-Stevens Fishery Conservation and Management Act 1972

- Endangered Species Act 1973, (as reauthorized in 1988) (ESA)
- Alaska National Interest Lands Conservation Act 1980 (ANILCA)
- The Greens Creek Land Exchange Act 1995
- City and Borough of Juneau Large Mine Review Ordinance 2003
- Executive Orders (EO):

  EO 12962 – Recreational Fisheries

  EO 11988 – Flood Plain Management

  EO 11990 – Protection of Wetlands

  EO 12898 – Environmental Justice

  EO 12088 – Water Quality Standards

  EO 13186 – Migratory Birds

Permits and Decisions for Continued Operation of the Greens Creek Mine

- Greens Creek Tailings Disposal – EIS ROD - USDA Forest Service and cooperating agencies
- Approval of expansion of the lease - USDA Forest Service
- Approval of changes to the GPO - USDA Forest Service
- Readjustment of the Reclamation Bond - USDA Forest Service, DEC, DNR, and CBJ
- NPDES Permit – EPA (expires in 11/03)
- Section 404 permit for fill of wetlands, U.S. Army, Corps of Engineers
- Waste Management Permit – DEC
- Coastal Zone Consistency Determination – CZM/DNR
- Large Mine Permit – City and Borough of Juneau

1.6.1 Federal Government

Forest Service (USDA FS)

The Forest Service is the lead agency in the preparation of the EIS for the proposed project. If another agency cannot meet its regulatory responsibilities,

the Forest Service is ultimately responsible for ensuring that federal and state regulations are implemented on National Forest System lands.

In addition to evaluating the proposed action for NEPA compliance, deciding among the various alternative actions, and approving or modifying the GPO, the Forest Service is responsible for ensuring the following:

- Compliance with Section 503 of the Alaska National Interest Lands Conservation Act (ANILCA), which provides for development of the Greens Creek Mine project
- Compliance with the Greens Creek Land Exchange Act of 1995
- Consistency with 1997 Tongass Land and Resource Management Plan, as amended (Forest Plan)
- Compliance with Section 106 of the National Historic Preservation Act
- Compliance with Sections 313 and 319 of the Clean Water Act
- Compliance with pertinent Executive Orders

The Forest Plan provides the land management direction for the Tongass National Forest. Forest Plan Land Use Designation (LUD) for the Greens Creek Mine is Non-Wilderness National Monument with an Overlay of Minerals. After the conclusion of mine operations, the area will be managed as a Non-Wilderness National Monument LUD. This LUD and the corresponding management prescriptions direct what, where, and how much proposed activity the Forest Service can authorize.

The Forest Plan contains many forest-wide standards and guidelines that apply to all LUDs on National Forest System (NFS) land. Chapter 4 of the Forest Plan addresses these specific standards and guidelines for minerals and geology as they apply to protection and management of different forest resources. These forest-wide standards and guidelines are used in conjunction with the additional standards and guidelines included within each management prescription for individual LUDs. All authorized changes to the Greens Creek Mine plan of operations must be consistent with the Forest Plan.

The following segments from the Forest Plan summarize the goals, objectives, standards and guidelines as they apply to the proposed Greens Creek Mine proposed tailings expansion.

Management Prescription for: Nonwilderness National Monuments (Land Use Designation NW)

Goals

To manage Admiralty Island and Misty Fiords National Monuments for public access and uses consistent with the Wilderness Act of 1964, the Alaska National Interest Lands Conservation Act of 1980 (ANILCA) and their respective Presidential Proclamations of 1978 which designated these units as National Monuments because of their superlative combination of significant scientific and historical features.

> Admiralty Island, exclusive of the Mansfield Peninsula, was designated as a National Monument for the scientific purpose of preserving intact a unique coastal island ecosystem. The goal of preservation was to assure continued opportunities for study of Admiralty Island's ecology and its notable cultural, historical, and wildlife resources, within its relatively unspoiled natural ecosystem. Protection and study of Tlingit cultural resources, other historical resources, brown bear and bald eagle populations are specifically directed.

To facilitate the development of significant mineral resources located within portions of Admiralty Island and Misty Fiords National Monuments, as specified by the Alaska National Interest Lands Conservation Act (ANILCA).

To protect objects of ecological, heritage, geological, historical, prehistorical, and scientific interest, as specified by ANILCA, and in Plans of Operation, and to minimize effects on non-mineral resources to the extent feasible. In the long-term, when mining is completed, to reclaim areas disturbed by mining to a near-natural condition.

To limit mining activities to claims with valid existing rights, and to the land area actually needed to carry out mining operations.

Objectives

Ensure that Plans of Operations for each mineral development specify the activities to be conducted, the location and timing of those activities, and how the environment and resources in each area will be protected through compliance with Federal and state requirements.

In areas affected by mining, manage activities to maintain the productivity of anadromous fish and other foodfish habitat to the maximum extent feasible. Stress protection of fish habitat to prevent the need for mitigation.

Standards & Guidelines for: MINERALS and GEOLOGY

Minerals and Geology Administration: MG12

II. *Forest Lands Open To Mineral entry*

A. Encourage the exploration, development, and extraction of locatable and leasable minerals and energy resources.

B. Assure prospectors and claimants their right of ingress and egress granted under the General Mining Law of 1872, ANILCA, and the National Forest Mining Regulations (36 CFR 228).

C. Permit reasonable access to mining claims in accordance with the provisions of an approved plan of operations.

III. *Plan of operations*

A. A Notice of Intent and/or a plan of operations is required for locatable, leasable, and salable minerals. (Consult FSM 2810, 2820, 2850, and 36 CFR 228.)

1. A plan of operations will receive prompt evaluation and action within the time frames established in 36 CFR 228.

2. Conduct an environmental analysis with appropriate documentation for all operating plans.

B. Work with claimants to develop a plan of operations that adequately mitigates adverse impacts to Land Use Designation objectives. Include mitigation measures for locatable and salable minerals and standard and special stipulations in leasing actions that are compatible with the scale of proposed development and commensurate with potential resource impacts.

1. Maintain the habitats, to the maximum extent feasible, of anadromous fish and other foodfish, and maintain the present and continued productivity of such habitats when such habitats are affected by mining activities. Assess the effects on populations of such fish in consultation with appropriate state agencies. (Consult ANILCA, Section 505(a).)

2. Apply appropriate Transportation Forest-wide Standards & Guidelines to the location and construction of mining roads and facilities.

3. Reclaim disturbed areas in accordance with an approved plan of operations.

4. Apply Best Management Practices (BMP's) to maintain water quality for the beneficial uses of water. (Consult Appendix B of the Forest Plan and Forest Service Handbook 2509.22.)

5. Periodically inspect minerals activities to determine if the operator is complying with the regulations of 36 CFR 228 and the approved plan of operations.

IV. *Bonds*

A. A bond may be required for locatable, leasable, and salable mineral operations to ensure operator performance and site reclamation are completed. (Consult 36 CFR 228.)

V. *Mineral Materials*

A. Permit mineral material sites only after an environmental analysis assures other resources are adequately protected, the site location and operating plan are consistent with the Land Use Designation emphasis and such resources are not reasonably available on private land. Require bonds and reclamation as appropriate. (Consult FSM 2850 and 36 CFR 228.)

B. Where the opportunity exists, design, excavate, and reclaim material sites to facilitate their use for dispersed recreation or other desirable uses such as conversion to salmonid rearing ponds and spawning channels.

All alternatives are consistent with the Forest Plan. The Land Use Designation (LUD) for Greens Creek Mine is Non-Wilderness Monument with an Overlay of Minerals. After the conclusion of mine operations, the area will return to a Non-Wilderness National Monument LUD.

Prior to approving a revision to the existing GPO, the Forest Service must comply with Section 106 of the National Historic Preservation Act (NHPA). Compliance with the NHPA generally involves the following:

- Identification of historic properties that might be affected,
- Assessment of effects to those properties,
- Consultation with the State Historic Preservation Office and interested parties, and
- Consideration of comments by the Advisory Council on Historic Preservation if historic properties could be affected.

National Historic Preservation Act

Prior to approving a revision to the existing GPO, the Forest Service must comply with Section 106 of the National Historic Preservation Act (NHPA). Compliance with NHPA generally involves the following:

- Identification of historic properties that might be affected,
- Assessment of effects to those properties,

- Consultation with the State Historic Preservation Officer (SHPO) and interested parties, and
- Consideration of comments by the Advisory Council on Historic Preservation if historic properties could be affected.

Clean Water Act

Under agreement between the Forest Service and the Alaska Department of Environmental Conservation (ADEC), the Forest Service is committed to ensuring that activities on National Forest System lands are consistent with the requirements of the Clean Water Act (CWA) Sections 319(b)(2)(f); 319(k); 313; and Executive Order 12088. Section 319 addresses nonpoint source pollution, and Section 313 and Executive Order 12088 require the Forest Service to adhere to the goals set forth in state water quality standards.

U.S. Environmental Protection Agency (EPA)

EPA is a cooperating agency with the Forest Service on the proposed project. EPA is responsible for the following:

- Compliance with NEPA for Permits Under Its Jurisdiction
- Oversight of NEPA compliance by other federal agencies
- Compliance with Clean Water Act (CWA)
- Compliance with Clean Air Act

EPA has primary responsibility for implementation of Sections 301, 306, 311, and 402 of the CWA. The agency shares responsibility for Section 404 with the U.S. Army Corps of Engineers.

Section 402 of the CWA establishes the National Pollutant Discharge Elimination System (NPDES) program. This program authorizes EPA to permit point source discharges of effluent, including process wastewater and storm water. Discharges must meet all effluent limitations, including water quality-based and technology-based limitations established under other CWA sections. The Applicant's NPDES permit expires in November of 2003, and issues concerning its modification will be addressed as part of this EIS process.

Section 404 of the CWA authorizes the U.S. Army Corps of Engineers to issue permits for the discharge of dredged or fill materials into waters of the United States. EPA also has authority under Section 404 for reviewing project compliance with Section 404(b)(1) guidelines, Section 404(b) elevation authority, and Section 404(c). Under Section 404(c), EPA may prohibit or withdraw the specification (permitting) of a site upon determination that the

use of the site would have an unacceptable adverse effect on municipal water supplies, shellfish beds, fishery areas, or recreational areas.

Section 309 of the Clean Air Act requires EPA to review and comment on EIS's prepared pursuant to NEPA.

U.S. Army Corps of Engineers (COE)

COE is a cooperating agency with the Forest Service on the proposed project. COE is responsible for the following:

- Compliance with NEPA for Permits Under Its Jurisdiction
- Compliance with Section 404 of the Clean Water Act (permits for dredge and fill)

Section 404 of the CWA authorizes COE to issue permits for discharge of dredged or fill material into waters of the United States. The act prohibits such a discharge except pursuant to a Section 404 permit. Activities involving the initial fill of tailings storage, treatment, and disposal are among those requiring a Section 404 permit. COE is responsible for determining whether a proposed action complies with Section 404(b)(1) guidelines. A Section 404 permit cannot be issued without such compliance.

All federal agencies, including COE, must comply with Executive Orders 11990 and 11988 with respect to impacts to the nation's wetlands and/or floodplains. The Corps' regulatory program provides flexibility when considering the national goal of "no net loss" for wetlands. Because this goal cannot always be achieved for each project individually, the Alaska District of COE may consider site-specific conditions and impacts when determining the extent of compensatory mitigation required for wetland losses.

Wetlands in the area to be affected by the proposed project were identified using the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (Federal Interagency Committee for Wetland Delineation, 1987). COE would regulate the placement of tailings at the disposal site as fill activity under Section 404. The EPA would regulate effluent discharge from the tailings facility under a Section 402 permit.

U.S. Fish and Wildlife Service (USFWS)

USFWS is responsible in this process for the following:

- Consultation on the Threatened and Endangered Species Act
- Compliance with the Bald Eagle Protection Act
- Coordination under the Fish and Wildlife Coordination Act

USFWS administers the Endangered Species Act, as reauthorized in 1982, the Bald Eagle Protection Act of 1940, as amended, and the Fish and Wildlife Coordination Act (FWCA). The Forest Service must consult with USFWS regarding any threatened or endangered species that might be impacted by the proposed project. If any impacts are projected, specific design measures must be developed to protect the affected species. The FWCA provides a procedural opportunity for the USFWS to coordinate with the Forest Service and offers means and measures to benefit fish and wildlife resources through mitigation of impacts to water resources and associated fish and wildlife.

National Marine Fisheries Service (NMFS)

NMFS is responsible in this process for the following:

- Consultation on Threatened and Endangered Species
- Consultation on Essential Fish Habitat
- Consultation on the Marine Mammal Protection Act
- Consultation on the Research and Sanctuaries Act

The Forest Service must consult with NMFS. If any impacts are projected to any threatened or endangered marine species or Essential Fish Habitat (EFH), specific design measures must be developed to protect the affected species.

1.6.2 State and Local Government

Alaska Department of Environmental Conservation (ADEC)

ADEC is responsible in this process for the following major permits that are required for the proposed project:

- Section 401 Certification of the COE Section 404 permit
- Section 401 Certification of the EPA NPDES permit
- Waste management permit for the construction, operation, and maintenance of the tailings disposal facility

ADEC is responsible for water and solid waste permits. Under Section 401 of the CWA, ADEC responsibilities include certification of the EPA NPDES permit and the COE Section 404 permit. ADEC must certify that the requirements of these permits would comply with state water quality standards. These standards include designation of the beneficial uses of the water, as well as numerical and narrative water quality criteria established to protect the beneficial uses.

Alaska Department of Natural Resources (DNR)

DNR is responsible in this process for approval of the reclamation plan. The plan must include a mandatory bonding provision, prohibit undue and unnecessary degradation, and contain performance standards requiring that lands be returned to a stable condition. The Dam Safety Officer of DNR is responsible for issuing a Certificate of Approval to construct the dam needed for the stormwater runoff pond.

The former Alaska Division of Governmental Coordination (DGC) transferred to DNR in the spring of 2003 and became the Office of Project Management and Permitting (OPMP). OPMP is responsible in this process for certification for compliance with the Alaska Coastal Management Program (ACMP). OPMP administers the ACMP and coordinates state reviews of activities in the coastal zone involving state and federal permits. In addition to coordinating projects that require state permits, OPMP is responsible for coordinating consistency reviews for direct federal actions and projects that require federal permits, such as those requiring NPDES permits.

Also in the spring of 2003, responsibility for issuing fish passage and habitat permits for activities that divert, obstruct, or change the natural flows of anadromous fish streams transferred to the DNR's Office of Habitat Management and Permitting (OHMP).

City and Borough of Juneau (CBJ)

CBJ is responsible for revision of the current Greens Creek Large Mine Permit. Under the recent revision to CBJ's ordinance, Greens Creek is classified as a rural mine and this revision can be accomplished through a summary approval process or a permit amendment. CBJ also participates in the review for consistency with the Juneau Coastal Management Program.

Chapter 2
Project Alternatives, including the Proposed Action

2 Project Alternatives, including the Proposed Action

Developing alternatives to the proposed action is an important step in the National Environmental Policy Act (NEPA) process. Through scoping, issues associated with the proposed action are identified that have the potential to significantly impact the environment (the *significant issues*). Alternatives to the proposed action are then formulated that could eliminate or lessen those specific impacts, while still meeting the underlying purpose and need. Alternative actions may also be combined with measures that *mitigate* the impacts. *Mitigation* can take a number of forms, but it often involves steps that rectify or repair the particular situation or that compensate in some way for the impact—such as by providing substitute resources or enhancing the value of a nearby environment.

Section 2.1 provides an overview of how identification of significant issues leads to the development of alternative actions and an overview of each of the alternative actions approved by the Forest Service. Section 2.2 discusses elements, including monitoring and mitigation that are common to all alternatives, including Alternative A, No Action. Section 2.3 discusses elements that are common to all action alternatives (Alternatives B, C, and D). Section 2.4 describes the four alternatives. Section 2.5 compares the four alternatives and Section 2.6 describes alternatives that were given initial consideration, but were eliminated from further comparison.

2.1 Issues and Alternatives Development

As discussed in Chapter 1, water quality and monument values were identified as the significant issues for this project. In response to these issues, the Forest Service developed and approved alternative actions to be addressed in this EIS.

Water Quality. For the proposed tailings expansion project, water quality is a significant issue. Each alternative that has been selected for full analysis in this document represents a potential means of improving the quality of water that comes in contact with the tailings (*contact water*) and isolating that contact water from ground and surface waters until its intended discharge.

This issue arises because of chemical processes that naturally occur within the tailings pile. The process of greatest concern is sulfide oxidation. As noted in the discussion of significant issues (Section 1.4), acidity is created through the process of sulfide oxidation. This process can lead to the release of sulfate and heavy metals into water. Carbonate minerals such as dolomite that are abundant in Greens Creek tailings neutralize the acidity, but the sulfate and metals may remain soluble in water at elevated concentrations.

Within the tailings pile, sulfate reduction occurs when organic materials are present. Sulfate reduction helps to reduce the concentrations of critical metals.

When sulfate is reduced by microorganisms, two by-products, sulfide and bicarbonate are produced. The sulfide ions tend to form insoluble compounds with certain metals such as zinc and nickel, thereby reducing their concentration.

Additionally, the bicarbonate tends to increase pH (reducing acidity), which can reduce solubility of other metals, especially zinc. As such, sulfate reduction is a beneficial process to be supported during the life of the mine and after closure.

Supporting the naturally occurring process of sulfate reduction, possibly by the addition of some form of carbon to the pile, and minimizing the contact between tailings, air, and water are the primary means for dealing with the process of sulfide oxidation and for ensuring that water quality in the project area does not degrade during the life of the mine or after closure. The geochemistry of tailings is discussed in more detail in Chapter 3.

Monument Values. Each alternative analyzed would require differing amounts of leased or disturbed area within the boundaries of the Admiralty Island National Monument. As part of the evaluation of each alternative, this document considers the impacts of the differing footprints and the potential for reclamation of impacted areas to pre-project conditions.

In each case, the actions considered are weighed against practical realities such as the potential environmental impacts to fish and wildlife as well as to the Monument, the degree of technical difficulty involved in implementation, safety, and the costs to KGCMC. It is the balance of these considerations that determine the overall feasibility of each action. Section 2.6 describes a number of alternatives that were eliminated from further consideration.

2.2 Elements common to all alternatives

There are a number of elements that are common to all alternatives including the No Action alternative. These items are described below.

- All discharged water will meet Alaska Water Quality Standards (AWQS).
- No new roads outside of the tailings lease area will be constructed (Roads will be constructed within the lease area atop the slurry walls, on the pile itself, and to pile facilities within the disturbed area of the pile lease area.
- The characteristics of the tailings, prior to the addition of any additives, are the same.
- A final 3H:1V (3 horizontal to 1 vertical) outer slope would be used for all tailings piles.

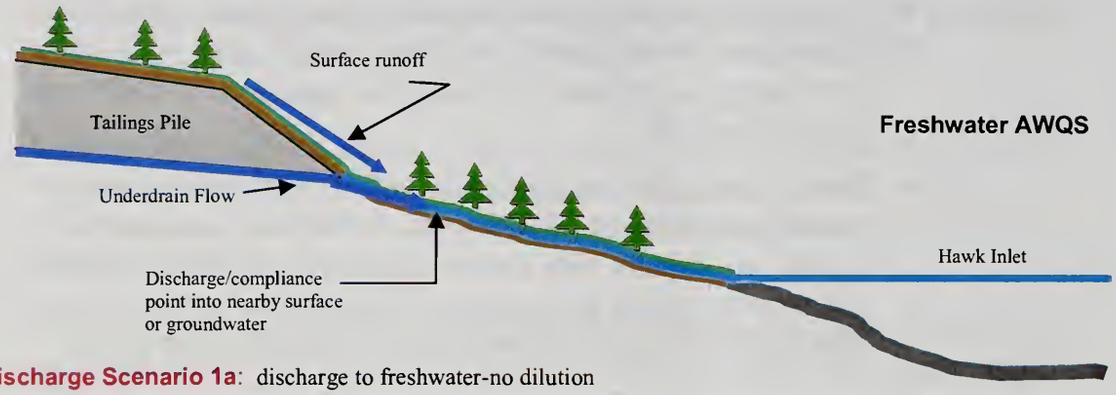
- The water treatment plant will be relocated.
- An engineered 4-layer soil cap would be placed over the pile after closure to minimize the infiltration of oxygen and water. The design (see Figure 2-3) would be approved by the Forest Service and DEC.
- During operation and for a period of years afterwards until discharges can meet AWQS without treatment, all water that comes into contact with the tailings along with other industrial waste water would be contained, collected and actively treated. Details of the water treatment process are described below.
- If upward groundwater gradients are not sufficient to provide containment of contact water, the facility design in the expansion area would also utilize a liner system to prevent discharge of tailings water into groundwater beneath the tailings.
- During mine closure and post-closure periods, water would continue to be treated until effluent quality is such that these treatment processes are not required in order to meet discharge requirements. At that time and depending on actual effluent quality, KGCMC would discharge water using one of these discharge/compliance scenarios, in decreasing order of preference. Diagrams of these scenarios are shown in Figure 2-1:

  (1) Discharge into nearby surface or groundwater (a) without dilution water from pile runoff and groundwater, or (b) with such dilution. This discharge would meet fresh water quality-based effluent limits;

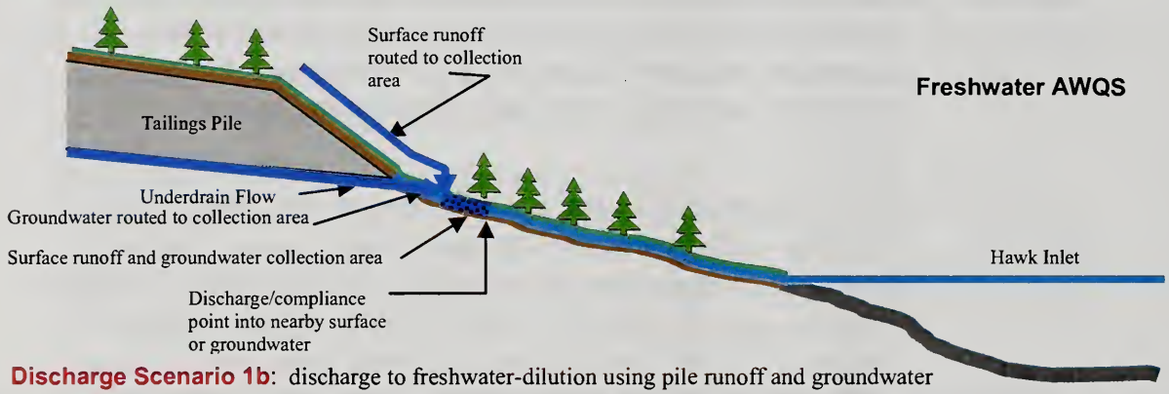
  (2) Discharge directly into Hawk Inlet. This discharge would meet marine water quality–based effluent limits with a potential dilution factor from a mixing zone; or

  (3) Continue to discharge into Hawk Inlet through a submerged diffuser. The effluent would meet the more stringent of either marine AWQS with a mixing zone or technology based limits.

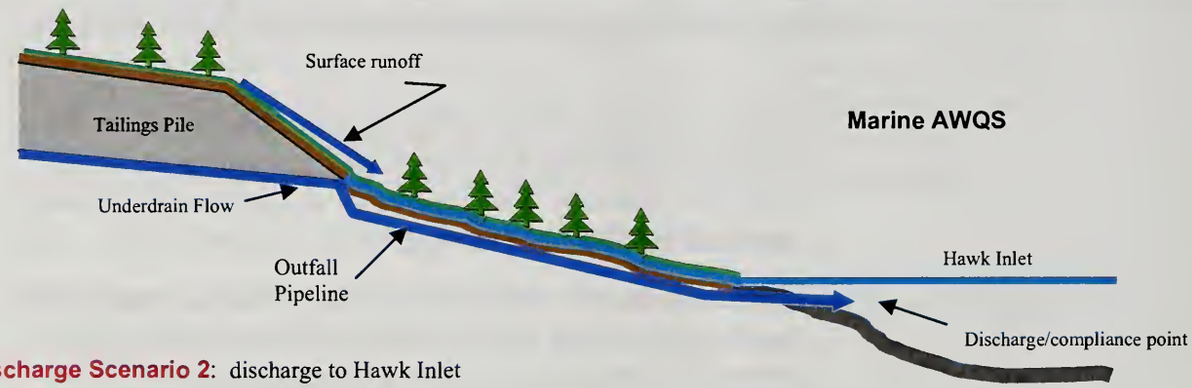
Figure 2-1 Water Discharge Scenarios



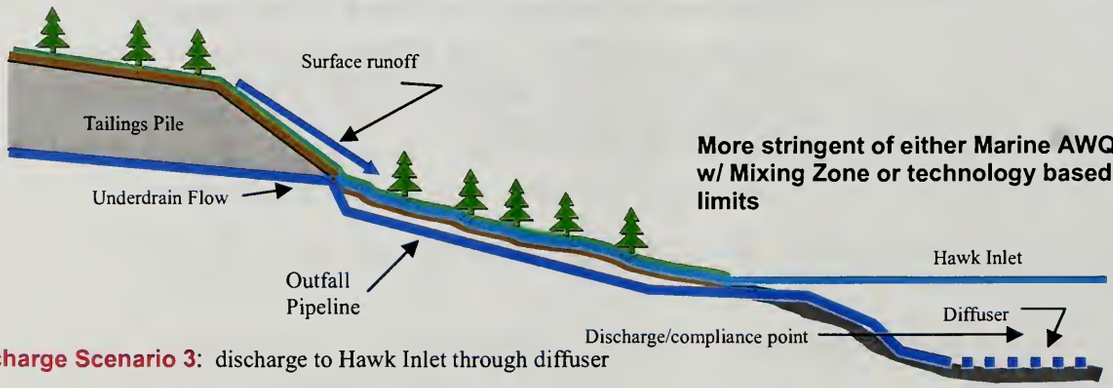
Discharge Scenario 1a: discharge to freshwater-no dilution



Discharge Scenario 1b: discharge to freshwater-dilution using pile runoff and groundwater



Discharge Scenario 2: discharge to Hawk Inlet



Discharge Scenario 3: discharge to Hawk Inlet through diffuser

2.2.1 Water Management

As described earlier, water that comes in contact with the tailings must be managed to ensure that it does not degrade the quality of surface and ground water. A combination of measures is used to manage water in and around the tailings pile. These measures include a system of diversions, collection ditches, French drains, finger drains, blanket drains, sumps, and temporary capping of the pile. For all action alternatives, some combination of these measures would be used to manage water.

Surface Water

Under the current GPO, KGCMC uses a ditch around the perimeter of the tailings pile to capture surface water that comes in contact with the tailings. A stormwater surge pond captures extra runoff water resulting from higher than usual levels of precipitation. The captured runoff water is routed to treatment facilities at Pit 5.

Because an expansion of the pile footprint under Alternatives B, C, and D would result in more surface water runoff, the construction of a second stormwater surge pond would be required. This second pond would be constructed on the southwest edge of the expanded area west of the existing Pond 6. The new pond would be sized to contain the 25-year, 24-hour runoff event. Captured runoff water would continue to be routed to the existing water treatment plant at Pit 5 or to a relocated treatment plant on the southwest corner of the expansion area. Figure 2-2 shows the proposed structures associated with the completed expansion project.

Groundwater

An existing, low permeable clay/silt layer naturally underlies some of the area under the proposed expansion of the tailings footprint of Alternatives B, C, or D. In those areas where bedrock or some other more permeable layer exists, a low permeability liner would be required. The low permeability layers, together with a series of slurry walls and French drains would collect the contact water and prevent it from seeping into the groundwater. (EDE, 2002a)

The system would also prevent rising groundwater from coming in contact with the tailings. As with the surface runoff water, captured drainage water would be routed to the Pit 5 water treatment plant or to a relocated facility for treatment and discharge to Hawk Inlet under the mine's NPDES permit.

Water Treatment

KGCMC would continue to operate its water management system in its present state. The cycle of water management begins with the collection of

fresh water for mine and mill process use. Water used in the mill process accounts for a majority of the water that must be treated prior to discharge into Hawk Inlet. Other wastewater routed to the tailings pile water containment/ treatment facilities originates from:

- Domestic wastewater and stormwater from the Hawk Inlet operations area,
- Tailings pile contact water and stormwater runoff,
- Mine area stormwater and domestic wastewater, and
- Waste rock area stormwater.

The central wastewater collection and redistribution facilities are Tank 6 and Pond 6 at the tailings pile. Water is collected in the wet wells and pumped to these containment facilities. From these surge/storage facilities, wastewater is routed to the Pit 5 treatment plant located on the north side of the tailings pile (Figure 2-2). After treatment, wastewater is discharged by pipeline through a submerged diffuser in Hawk Inlet under a National Pollutant Discharge Elimination System (NPDES) permit.

The Pit 5 treatment plant consists of two treatment process systems. The primary plant is a chemical precipitation plant having an operating capacity of 1250 gpm. The secondary plant is a filtration plant with a capacity of 1200 gpm. The combined capacity is approximately 1800 gpm.

The primary treatment process consists of a mixing tank where ferric chloride and lime are added to the water to precipitate solids. The water then moves into a reactor vessel where a polymer is added to assist in the separation of thickened sludge from the water. The treated effluent is discharged to the NPDES site (see Outfall 002, Figure 3-8), while the sludge is collected and filtered to a low moisture cake, transported to the tailings pile and buried.

The secondary plant consists of chemical addition for pH adjustment, then coagulant addition as needed. The water is then routed to three multi-media sand filters. The treated effluent is discharged to the NPDES site, while the filtered solids are back-washed into the Pond 6/Tank 6 water collection system and fed to the primary plant.

Treated wastewater from the treatment plants discharge through NPDES Outfall 002 (See Figure 3-8) a 160-foot long, 14-inch diameter diffuser to Hawk Inlet. NPDES water quality standards for the discharge are summarized in Table 2-1. The effluent guidelines for metals that apply to this permit are best available technology economically achievable (BAT), 40 CFR 440.103, whereas the limitations for pH and total suspended sediment (TSS) are based on best practicable control technology (BPT) 40 CFR 440.102. These

technology-based limitations for metals and the BPT limits for pH and TSS are also shown in Table 2-1.

Table 2-1 NPDES Outfall 002 Effluent Limits

Parameter	Effluent Limits	
	Monthly Average	Daily Maximum
Cadmium, µg/l [1]	50	100
Copper, µg/l [1]	150	300
Lead, µg/l [1]	300	600
Mercury, µg/l [2]	1.0	2.0
Zinc, µg/l [1]	500	1000
TSS, mg/l	20	30

Notes:
Range, average.
[1]Parameters analyzed as total recoverable.
[2]Parameters analyzed as total.

Under all alternatives water will continue to be treated during operations using existing treatment processes. During mine closure and post-closure periods, water will continue to be treated using existing treatment processes until such time that effluent quality is such that these treatment processes are not required in order to meet discharge requirements. At that time and depending on actual effluent quality, KGCMC would discharge water one of the following scenarios, in decreasing order of preference:

(1) Discharge into nearby surface or groundwater (a) without dilution water from pile runoff and groundwater, or (b) with such dilution. This discharge would meet fresh water quality-based effluent limits;

(2) Discharge directly into Hawk Inlet. This discharge would meet marine water quality–based effluent limits with a potential dilution factor from a mixing zone; or

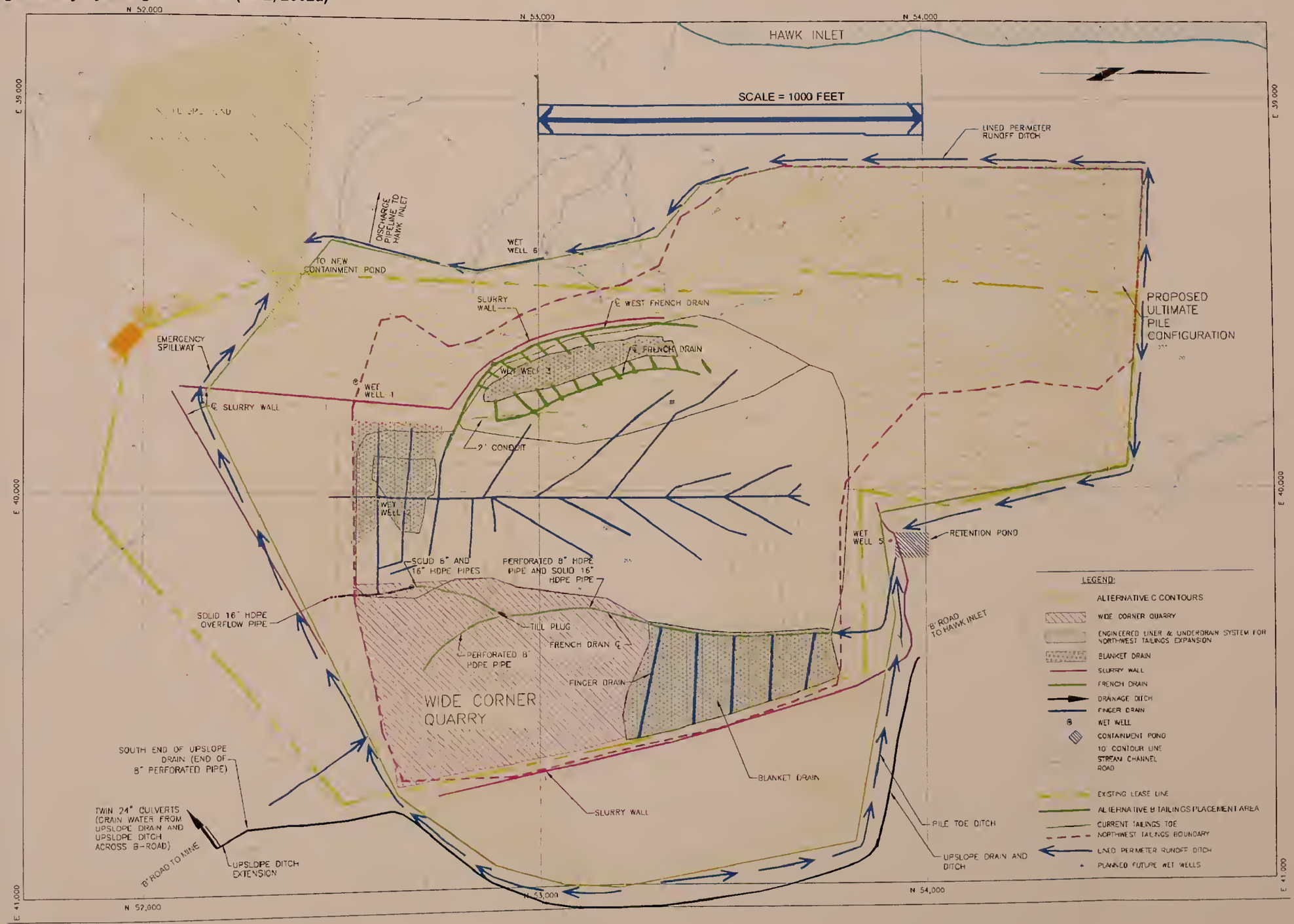
(3) Continue to discharge into Hawk Inlet through a submerged diffuser. The effluent would meet the more stringent of either marine AWQS with a mixing zone or technology based limits.

Any of these discharge scenarios would be conducted under a re-issued NPDES permit with any pertinent mixing zone authorized by ADEC.

The decision as to which discharge scenario will be utilized and when it will be implemented during the closure and post-closure period will be proposed by the Company to the regulatory agencies per the requirements set forth in

the GPO (KGCMC, 2001b). The logic used to support this decision is presented in Section 2.5.1. Once the agencies have confirmed through monitoring that the treatment plant is no longer required, it will be removed and the site reclaimed to return the area to generally natural conditions (KGCMC, 2001b).

Figure 2-2 **Tailings Facility Hydrologic Controls (EDE, 2002a)**



2.2.2 Water Management during Closure and Post-Closure *(Reclamation)*

When the mine has reached the limit of its remaining life and there are no more tailings for disposal, the pile and the surrounding areas would be closed. In conjunction with the closure, final reclamation efforts would be implemented to return the area to a near-natural condition.

Surface Water

As part of the closure and reclamation process, KGCMC would cap the tailings pile (for details of the capping process, see Section 2.2.5, Reclamation and Appendix C). Seeding would be done with standard techniques and monitoring to prevent the development of gullies. Once the cap is in place, runoff water would not come in contact with tailings. Nevertheless, the runoff would continue to be collected and treated until the topsoil and vegetation over and around the capped pile are stable. In less than a decade after closure, the cap would be stable and most of the area would have returned to a vegetated state. Water that falls on the pile after revegetation would be similar to what is normal in the unaltered surrounding area and it would be allowed to follow its natural courses. Due to the high amount of precipitation and the relatively cool temperatures, evaporation and transpiration amounts are relatively low at the tailings site. The balance of rainfall and evaporation off the reclaimed tailings surface are important factors that have been considered in the design of the engineered cover proposed for the tailings (USEL, 1998).

Groundwater

The cap on the tailings pile would be designed to reduce the amount of water that seeps into the pile and then needs to be managed. Drainage water would continue to be captured through the drain system, flow into the wet-wells, and subsequently be transferred to the water treatment plant. If conditions are such that the drainage water meets the state's water quality standards, it would be allowed to flow along its natural courses into Hawk Inlet.

2.2.3 Monitoring and Mitigation

The GPO and DEC Waste Management Permit specify visual, groundwater, surface water, leachate, biological, and post closure monitoring requirements. For water quality monitoring under this plan, KGCMC analyzes water quality samples from several wells upgradient and downgradient from the tailings pile. No new monitoring plan has been developed at this time because the existing plan is functioning appropriately within the existing tailings lease boundaries. If Alternative B, C, or D is selected and approved in the ROD,

modifications to the existing plan would be required to account for the change in the tailings lease boundary. The duration of monitoring is set by DEC. After closure, prior to cessation of monitoring, KGCMC must demonstrate ".... that all downgradient monitoring stations have been in compliance with Alaska Water Quality Standards (AWQS) for at least 3 years. Additionally, results of monitoring at internal sites must corroborate the finding that water quality downgradient of the facility will not change in the foreseeable future. DEC retains the right to extend monitoring requirements as long as it is needed.

In connection with requirements of the NPDES permit, monitoring of seafloor sediment and biota is also required by the EPA. The Forest Service has consulted with the National Marine Fisheries Service (NMFS) on Essential Fish Habitat. Regardless of alternative adopted, the NMFS will make recommendations to the Forest Service and EPA for additional marine monitoring requirements to be adopted as requirements of KGCMC's renewal of its NPDES permit, which will occur in early winter of 2003.

Mitigation

If monitoring detects exceedances or violations, contingency plans would be required to be developed to mitigate the specific violation. Concurrent reclamation and reclamation after closure (discussed in the following section), including wetland creation and road removal, are also mitigation measures built into the GPO and Waste Management Permit. Additional mitigation measures are set forth in Section 4.17.3, Guiding Principles from Existing Standards, Criteria, and Policies that Control the Management of Natural Resources of Concern, and Section 4.11, Marine and Aquatic Habitats, Biota, and Essential Fish Habitat – Mitigation.

2.2.4 Concurrent Reclamation

Because the tailings pile presently is an active site, it has limited opportunities for concurrent reclamation projects. Interim reclamation activities are, however, in use at the site and include erosion controls, hydroseeding, and water drainage systems. The western and southern slopes of the existing pile have been covered with a protective layer of topsoil and were hydroseeded in 2001. Concurrent reclamation projects would become available within 2 to 5 years on the northeast sides of the tailings as the pile expands upward. As areas become available, KGCMC would initiate reclamation planning.

2.2.5 Temporary Closure and Reclamation After Closure

The Greens Creek mine is a poly-metallic mine. Lead and gold account for approximately 20% of the value of the mine's production, with zinc and silver accounting for the remaining 80%. Depending on the respective prices of zinc and silver, the mill process is optimized for whichever metal produces the better return. Though zinc prices are currently low, improvements to the milling process since the mine reopened have lowered the production costs per ounce for these metals.

Section 2.3 Alaska Department of Environmental Conservation Waste Management Permit (Appendix D) provides terms for the temporary closure of the mine, including submission of a conceptual temporary closure plan to the Department followed by submission of a detailed temporary closure plan to the Department within 60 days after shutdown of all mill processes. Both plans require approval by the Department and must include:

- Procedures, methods, and schedule for the collection, treatment, disposal or storage of leachate;
- Management practices designed to control surface and ground water drainage to and from the facility and the surrounding area;
- Secure storage of chemicals during the period of closure;
- Management practices designed to minimize oxygen and moisture entry into the waste;
- Continued monitoring and reporting activities as if the facility were actively accepting waste; and
- Complete concurrent reclamation on all areas that have achieved final elevation, except to the extent that completion of concurrent reclamation would impair the ability to perform work on adjacent areas upon recommencement of operations, and satisfy corrective action requirements as appropriate under this permit and the Reclamation Plan.

The goal of the reclamation plan is to return the disturbed areas to a near natural condition. The standards for tailings reclamation include compacting the pile, sloping the surfaces, and diverting water to minimize erosion and to keep both water and air from getting into the tailings. The outer surfaces of the pile would have been constructed at the standard slope 3H:1V (3 horizontal to 1vertical) to minimize additional grading for final closure.

Tailings reclamation would begin with construction of a cap for the pile. This cap would consist of four layers of engineered soil cover designed to minimize the amount of air and water entering the tailings pile (USEL, 1998; Klohn-Crippen, 2001). Covers similar to the engineered cover proposed at Greens Creek have been designed and constructed by Dr. Ward Wilson at numerous mine sites in British Columbia, Saskatchewan, and in subtropical regions of Australia. Figure 2-3 presents a schematic diagram of placement of a typical four-layer engineered reclamation cover, and Table 2-2 summarizes the characteristics of each layer.

- Lower Capillary Break. The first layer would consist of 8 to 12 inches of drain rock placed immediately on top of the tailings. This would function as a lower capillary break to drain seepage from the layers above and to remove water that wicks up through the tailings. This rock would be non-mineralized and would come from mining operations or local borrow sources.
- Compacted (Barrier) Layer. The second layer would be 24 inches thick and would be composed of a clay/gravel soil screened from on-site sources. This would be a compacted, low permeability barrier layer that would minimize water and oxygen infiltration to the tailing pile.
- Upper Capillary Break. The third layer would consist of another 8 to 12 inches of drain rock with filter fabric on top. It would function as an upper capillary break in the same manner as the first layer.
- Growth Layer. The fourth layer would be composed of 24 inches of growth material from overburden removed from the tailings site and stored on the lease area. This material would support revegetation as well as provide recharge water to the underlying compacted layer. The cap is designed to function with the growth and eventual fall of large conifers on the cap.

To breach the integrity of the cap, the roots of a fallen tree would have to:

- Extend through the top layer of 24 inches of growth material (plus any additional thickness that would occur from rotted vegetation in the 100 to 150 years it would take for any hemlock or spruces to grow to full size),
- Extend through the 8 to 12 inch layer of drain rock, and
- Extend far enough into the 24 inch compacted clay/gravel layer to disrupt the integrity of this layer when the tree fell.

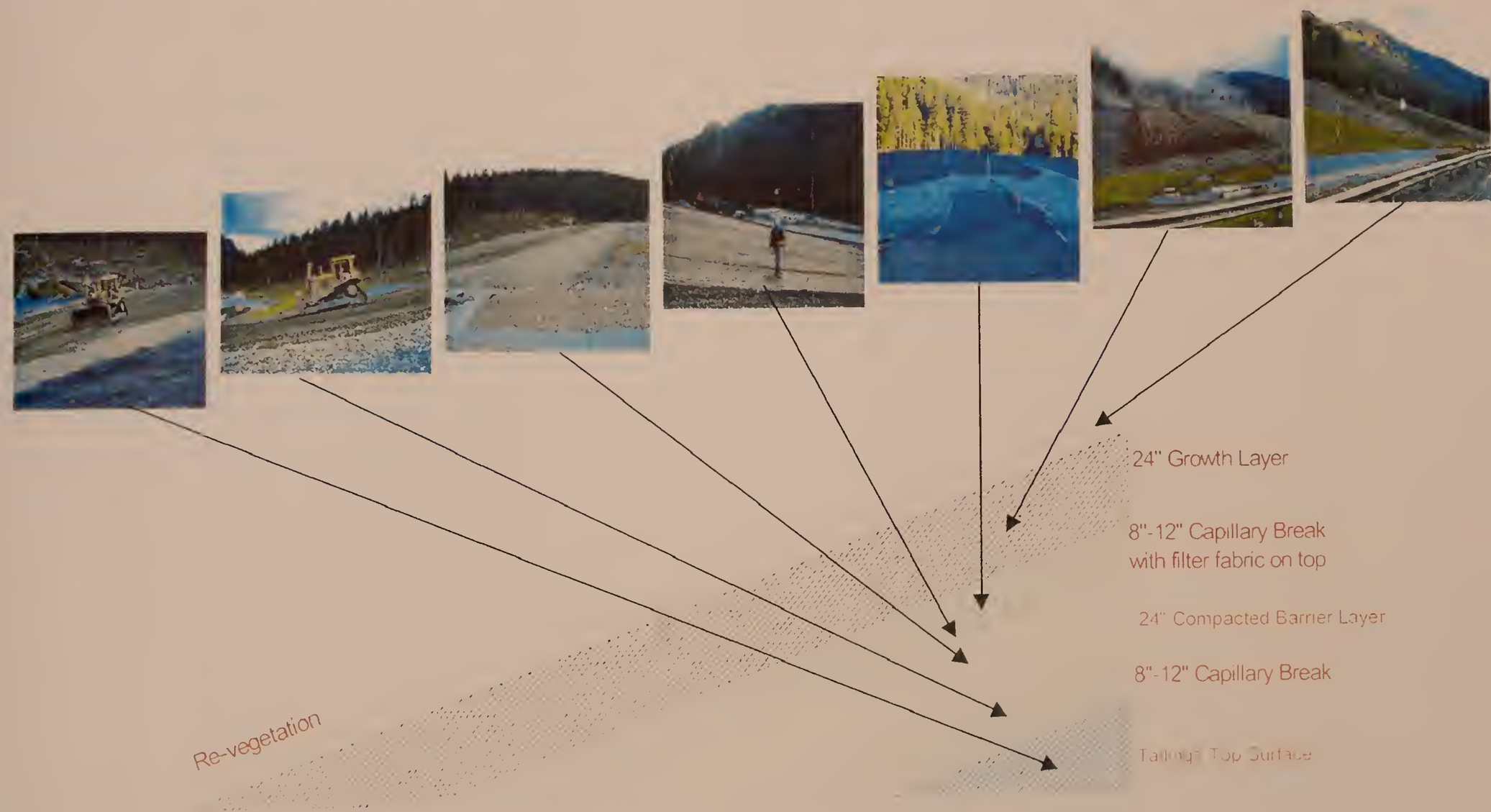
In dry areas where trees have deep tap roots to reach water, such as the Richmond Hill Mine in South Dakota, tree growth on the mine covers has been prohibited because of the potential of blow downs to disrupt the cap (Schafer, 2001). In Southeast Alaska the root structures of hemlock and spruce trees are typically very shallow. Greens Creek has informally measured the thickness of the root wads of a number of fallen old growth trees in the vicinity of the mine and tailings facility and have not found any that extend to 24 inches in depth, less than the depth of the top layer of the cap. When blow down does occur, the dirt from the root falls back into the hole over the next several years and over time the hole evens with the rest of the forest floor. Under all alternatives considered in this analysis, KGCMC would be required to conduct a study that addresses long-term issues related to tree blow down, as per conditions set by the ADEC Draft Waste Management Permit (Appendix D).

Appendix A, *Hydrology and Geochemistry of the Greens Creek Tailings Facility 2002*, discusses cap performance and the inputs regarding evapotranspiration and cap runoff that were used in the stochastic model used to predict water quality under the different alternatives.

Table 2-2 Four Layer Reclamation Engineered Cover Characteristics Summary – (Source: KGCMC, 2001a)

Layer	Purpose	Design Compaction	Design Consideration	Materials	Thickness
Growth Layer	Vegetation support, erosion control and moisture retention	Loose placement, tracked in with heavy equipment. Estimated permeability rate 10E-2 to 10E-3 cm/sec	Appropriate thickness for water retention, freeze and vegetative protection	Topsoils, native sands/gravel mix.	24" minimum
Upper Capillary Break	Suction break and water drain between major cover layers	Loose placement, tracked in with heavy equipment.	Drains excess water from top of compacted layer and acts as a suction break to prevent upward water migration in dry periods	Clean drain rock less than 3 inches and greater than 1 inch in diameter Install filter fabric on top of layer, before growth layer.	8" - 12"
Compacted (barrier) Layer	Minimizes air and water infiltration to layers below	Highly compacted to 95+% of Proctor. Estimated permeability rate 10E-6 cm/sec minimum	Low infiltration. This layer is designed to stay 85% saturated to minimize air and water infiltration	Rock less than 2 inches in diameter, with high fines percentages (+20%) to maximize compaction and minimize permeability	24"
Lower Capillary Break	Suction break and water drain beneath cap layer	Loose placement, tracked in with heavy equipment.	Drains excess water from top of tailings surface and infiltration from above and acts as a suction break to prevent upward water migration in dry periods	-3" to +1" clean drain rock	8" - 12"
Tailings	Storage of materials from the mine and mill for continued production	Compacted to GPO specifications during operations placement	Placed and compacted to minimize oxidation of tailings materials, and to promote stability of the pile structure	Tailings and mine production rock	Thickness varies, placed in 3H:1V final outside slope

Figure 2-3 **Typical Four Layer Engineered Reclamation Cover**



Typical Four Layer Engineered Reclamation Cover

Non Wetlands

Once the cap is in place, the growth layer would be hydroseeded using a Forest Service approved seed mix. Hydroseeding would provide for a quick, one- to two-year vegetative cover to stabilize the area and prevent erosion. It would also act as a seedbed for the eventual regeneration of natural forest cover.

Regeneration of the forest with species that are native to the Admiralty Island National Monument is the Forest Service standard. Although the entire process would take many decades, data from areas already revegetated within the mine project area show initial tree reestablishment in three to ten years. The time varies depending on site conditions and distance from a mature forest seed source.

Wetlands

In 1993-1995, the U.S. Corps of Engineers found that wetlands creation is feasible in the Greens Creek environment. Although the sites are as yet undetermined, KGCMC has committed to COE to reclaiming an additional two acres as wetlands.

For this undertaking, KGCMC would identify sites that exhibit an existing ability to maintain enough water year-round for effective re-establishment of a wetlands environment. These sites would be located within the lease boundary southwest of the pile (See Figure 4-9). Site selection would be subject to approval by COE.

If necessary, the sites would be contoured to ensure the presence of enough water to support the desired environment. Soils typical of, and suited to, wetlands areas would be recovered or borrowed and used as appropriate. Designs would incorporate open water and vegetated wetlands as the specific site conditions allow. Wetlands vegetation would be established through seeding of appropriate plant species, or transplanting from borrow areas.

2.3 Additional elements common to all action alternatives:

- The tailings placement footprint is designed to provide tailings storage for the anticipated remaining 22 year life of the mine (approximately 12 years at present rate of production for known reserves and 10 years for potentially developing undiscovered reserves).
- The finished height of the pile would be approximately 160 feet above ground level (330 feet above sea level). Its existing height is 80 feet above ground level.

- Placement of tailings could necessitate the relocation of the water treatment plant and a portion of the mine access road. Other than the relocation of this portion of the road, no new road construction is associated with any alternative.
- A Design Basis Earthquake (DBE) for operations (Crustal Earthquake –1/475 year, M6.5) and a Maximum Design Earthquake (MDE) for closure design (equal to 75% of Maximum Credible Earthquake, M7.0).
- Interception and diversion systems to control non-contact water around the treatment facility, as similar systems currently function.
- Approved containment structures (such as liners where appropriate, slurry walls, and low-permeability deposits, as are now in use) to protect both groundwater and adjacent surface water.
- Water would continue to be treated at a water treatment plant as described under Alternative A.
- The Pit 5 water treatment plant would be moved to a new location within the expanded lease area.
- Construction of a new water management pond system designed for a 25-year, 24-hour runoff event. The ponds would utilize a low-permeability liner as used in the existing stormwater ponds. Installation of surface water and groundwater controls and diversions.
- Drainage infrastructure sufficient to meet geotechnical requirements to minimize phreatic levels within the tailings pile.

2.4 Alternatives

2.4.1 Alternative A – No Action

The "No Action" alternative would not modify the existing general plan of operations to permit any expansion of the tailings disposal facility. Kennecott Greens Creek Mining Company would continue its present method of generating whole tailings. The tailings would be placed without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit. The tailings pile would be limited to 29 acres in size. Under the current permit the existing tailings facility has space for about 600,000 additional tons of tailings. At current rate of production, KGCMC would run out of room for tailings surface disposal in roughly 2 years without a permitted expansion of the pile.

Alternative A assumes that mining operations continue as they are now (Figure 2-4). The *no action* alternative is required by NEPA and serves as the base line for describing the potential effects of the other alternatives.

The general plan of operations (GPO) for the Greens Creek mine would stay as it is, KGCMC would continue to use its present method for disposing of tailings and the tailings facility lease area would not increase from the current permitted 56 acres. The tailings footprint for the tailings pile is currently 23 acres and would increase to the currently permitted size of 29 acres. The remaining 27 acres would be used for related infrastructure such as water treatment facilities, storm water storage ponds, and access roads to the tailings pile.

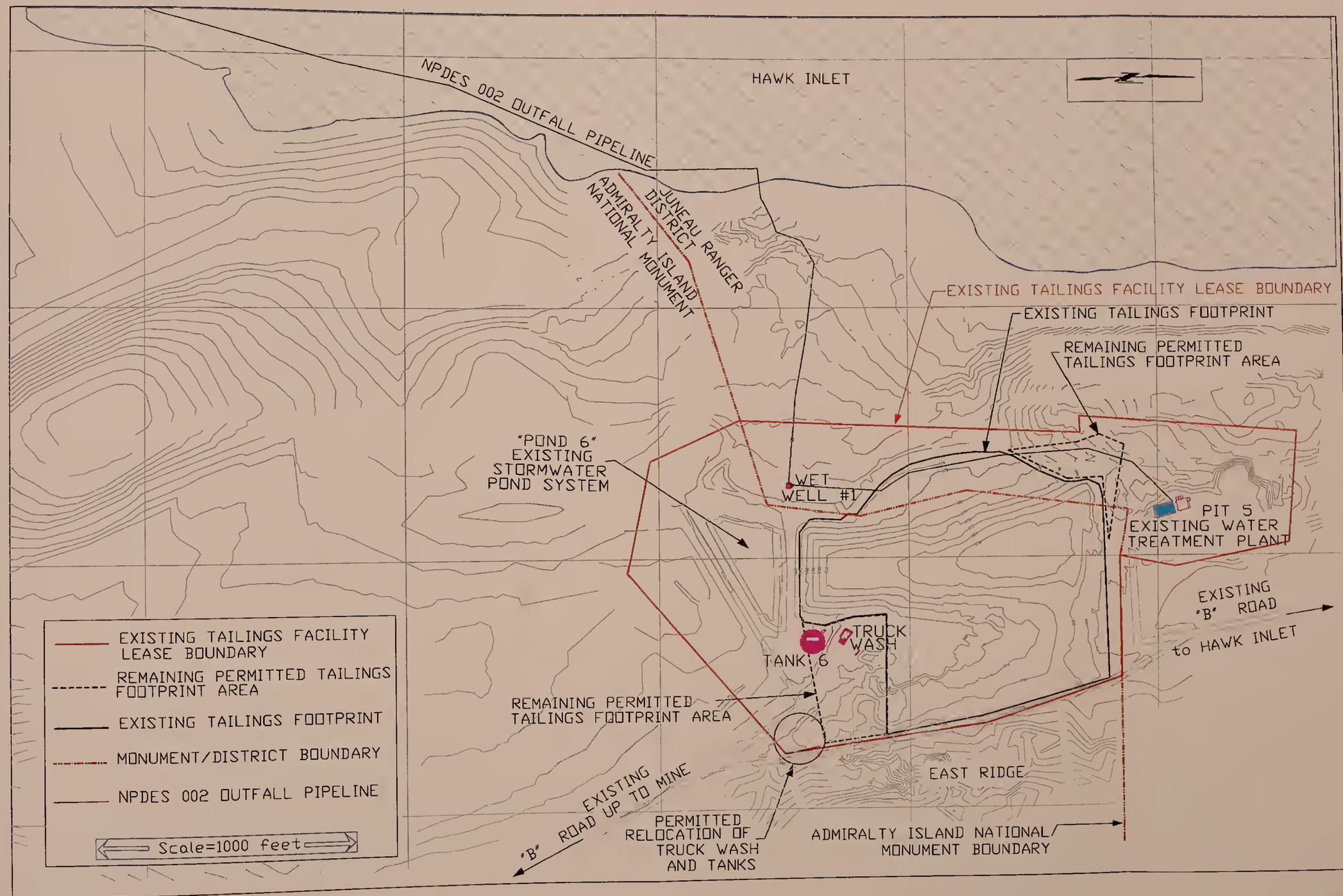
KGCMC would continue to place tailings in a dewatered state onto the tailing pile to a height above original ground surface of about 80 feet for a maximum elevation above sea level of 250 feet; capping requirements would remain as they are.

A $ 0 cost of construction and implementation of Alternative A is used to as a basis for comparison to the other Alternatives. The actual cost of implementing this alternative is discussed more in Chapter 2, Section 2.5, Comparison of Alternatives, and in Chapter 4, Section 4.15 Socioeconomic consequences.

Water Quality. Contact water would continue to be collected, isolated and treated as described above in Section 2.2.1 Water Management and Section 2.2.2 Water Management during Closure and Post-Closure.

Monument Values. The representation in Figure 2-4 shows the areas of disturbance that would be inside and outside the monument. The existing lease boundaries would remain unchanged with 38 acres inside the monument and 18 acres outside the monument. Within this leased area tailings would be placed on 20 acres within the monument and 3 acres outside the monument.

Figure 2-4 Alternative A – No Action



2.4.2 Alternative B – Proposed Action

The Proposed Action alternative would modify the general plan of operations to permit an increase in the size of the tailings disposal facility. Kennecott Greens Creek Mining Company would continue its present method of generating whole tailings. The tailings would be placed without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit. The expanded tailings pile would occupy 61 acres.

Alternative B involves expanding the tailings facility lease area by 84 acres, primarily to the west and the south, increasing the total lease area to 140 acres. The footprint for the tailings pile would increase from the currently permitted size of 29 acres, to about 61 acres. Tailings would continue to be placed in a dewatered state onto the tailings pile, however the height would be increased by 80 feet above original ground surface to about 160 feet for a maximum elevation above sea level of 330 feet; capping requirements would remain as they are under the GPO. Table 2-3 provides an overview for comparing physical components of the alternatives. Figure 2-5 shows the boundary of the existing tailings facility lease area and the maximum footprint of the tailings pile within it (29 acres). The figure also shows the proposed expansion area, the expanded footprint of the tailings pile (about 40 additional acres), and the permitted tailings area.

Water Quality. Contact water would collected, isolated and treated as described above in Sections 2.2.1 Water Management and Section 2.2.2 Water Management during Closure and Post-Closure.

Monument Values. 90 acres of the lease area would be inside the monument and 50 acres outside the monument. Within this leased area tailings would be placed on 28 acres within the monument and 33 acres outside the monument.

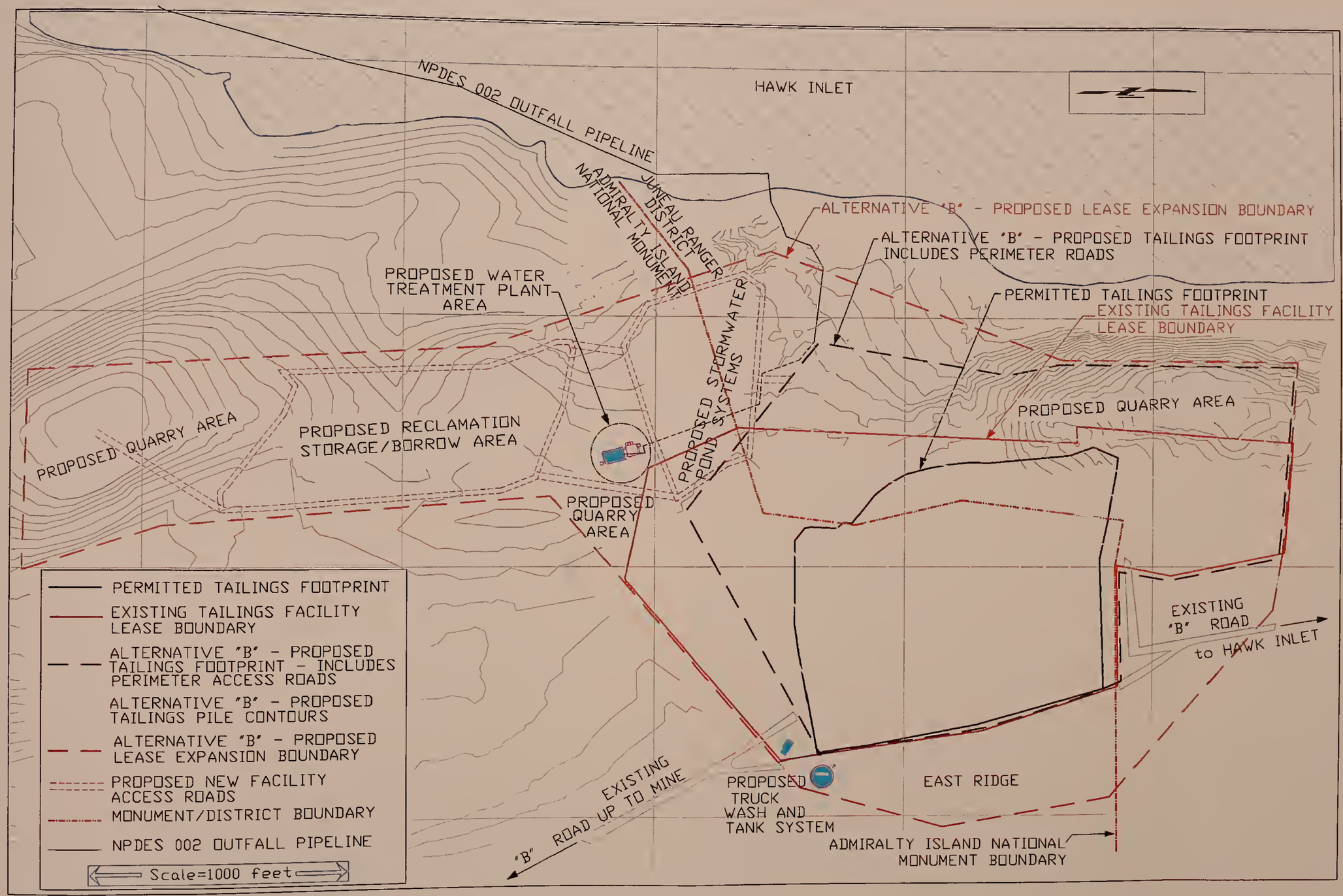
The expanded footprint is designed to be large enough to dispose of all the tailings produced during the remaining life of the mine—roughly 12 years at the present rate of production and known ore reserves. The footprint would also be large enough to dispose of tailings produced from the development of anticipated ore reserves.

Alternative B includes the following specific details:

- Expansion of the existing Pit 5 quarry to provide materials for infrastructure development and construction within the tailings disposal area (see Figure 2-5).

- Development of two new quarries within bedrock ridges in the southern portion of the expanded lease area. These quarries would provide materials for infrastructure development and for road construction as needed (see Figure 2-5).
- Construction of a new water management pond system for storm water storage and treatment (see Figure 2-5).
- Installation of surface water and groundwater controls and diversions, for expansion of the tailings pile (see Figure 2-2).
- Use of the existing containment Pond 6 for storage of sludge materials produced during tailings placement, and eventually for placement of tailings. Development of a storage area for excavated reclamation materials (topsoil and organics) (see Figure 2-5).
- Development of sand and gravel *borrow areas* (areas with needed materials) for development of infrastructure and storage of reclamation materials.
- The estimated cost of construction and implementation of Alternative B is in the range of $ 11,000,000 - $ 20,000,000.

Figure 2-5 Alternative B - Proposed Expanded Lease Area



2.4.3 Alternative C - East Ridge Expansion

Alternative C would modify the general plan of operations to permit expansion of the existing tailings disposal facility to the east of the present location and use of a continuous addition of carbon to the tailings during placement. Expansion to the east would minimize both the lease area and the disturbed area within the Admiralty Island National Monument and increase the geotechnical stability of the pile by using natural topographic features as a buttress for the pile. Like all alternatives, Alternative C would utilize the post-closure construction of an engineered soil cover on the pile to minimize infiltration of oxygen and water into the pile.

Another objective of this alternative is to provide greater assurance of long-term chemical stability of the tailings than with the proposed action through a continuous addition of carbon to the tailings during placement. Carbon is currently present in the tailings from mill floatation reagents and dewatering flocculants and biosolids from the Cannery wastewater treatment. Biosolids addition would be reviewed for placement methods and approved by the permitting agencies within one month of the ROD.

A sulfate reduction monitoring plan (SRMP) would be implemented to determine the effectiveness of the current level of carbon addition and its adequacy in maintaining a reducing environment in the pile during operations. The SRMP would identify the quantity of carbon required to assure a reducing environment following closure of the mine and thus eliminate the need for chemical/physical water treatment after mine closure. The SRMP would determine the need for supplemental carbon addition to ensure that sulfate reduction processes continue in order to meet water quality standards. The SRMP would be completed and its findings submitted to the regulatory agencies for approval within 30 months of the issuance of the ROD, and after approval, would be specified in the GPO.

Water Quality. Alternative C addresses the water quality issue by requiring the addition of sufficient carbon to the tailings pile to assure sulfate reduction throughout the life of the mine and post-closure. Sulfate reduction reduces sulfate to sulfide and produces bicarbonate. The sulfide ion combines with metal ions to form insoluble metal sulfides. This improves the water quality

by removing metals from the water. Sulfate reduction occurs due to the presence of certain microorganisms that consume organic (i.e., carbon) compounds under anaerobic conditions.

Sulfate reduction is known to occur within the existing pile, as measurable levels of dissolved sulfide are evident in water samples collected from two piezometers in saturated zone waters in the tailings. The likely persistence of sulfate reduction after facility closure and the uniformity of sulfate reduction within the tailings will influence the water chemistry of the effluent long after closure occurs. Sufficient carbon may need to be available post-closure to ensure that sulfate reduction continues to reduce metal ions to insoluble forms. This will result in effluent having lower metal levels over the long term. In this alternative, KGCMC would continue its present method of generating and storing whole tailings during the 30 months following the issuance of the ROD for this EIS. During that time, KGCMC would continue to evaluate sulfate reduction within the GPO Appendix 3 Tailings Internal Environment Monitoring Program (TIEMP) (KGCMC, 2001a) as a means to prevent zinc mobilization.

Carbon is presently added to the pile from the mill flotation reagents, dewatering flocculants and wastewater biosolids from the Cannery housing facility. Additional carbon from an external source may be required to assure long-term sulfate reduction and chemical stability of the tailings disposal facility. During the 30 months following the issuance of the ROD, KGCMC would continue to evaluate sulfate reduction within the tailings pile to determine the type and amount of Carbon needed to ensure sulfate reduction.

The 30 month period for development of the SRMP was arrived at during discussion at the Seattle meeting with the EPA, Forest Service, and DEC. Thirty months was deemed necessary to develop the program to allow adequate time for two field seasons and associated data collection, laboratory testing, field testing, analysis, and write-up.

KGCMC would also undertake an additional sulfate reduction monitoring program (SRMP), as outlined in Appendix B, including the monitoring of sulfate reduction processes within the pile. Monitoring results would determine the amount of carbon needed to assure that post-closure water quality meets applicable water quality or technology-based effluent limits without supplemental water treatment and whether supplemental carbon would need to be added. Additional carbon would be added to the pile unless the SRMP shows that the carbon added to the pile from sources such as the mill flotation reagents, dewatering flocculants and wastewater biosolids is sufficient to fuel sulphate reduction for a sufficient period of time post closure to ensure acceptable water quality in perpetuity.

If the need for supplemental carbon addition is identified from the monitoring results, the SRMP would also determine the best form of supplemental carbon addition, the required amount, and the best method of application. The SRMP discusses previous uses of supplemental carbon to fuel sulfate reduction and improve water quality.

The maximum quantity of carbon necessary to sustain sulfate reduction can be estimated on the basis of the rate of sulfide oxidation in the pile. Approximately 1,700 pounds of supplemental organic carbon per year may be required for an indefinite time (Appendix B). A lesser quantity of carbon may suffice for supporting sulfate reduction since only a portion of the sulfate need be reduced to sulfide to effect water quality improvements. Procedures for such an addition would be developed by KGCMC, submitted to the regulatory agencies for approval, and after approval, specified in the GPO.

Specific goals of the SRMP (Appendix B) include:

- Continued monitoring of sulfate reduction processes within the pile. This goal is one identified in the GPO Appendix 3, and would continue during operations through post-closure of the tailings pile.
- Determine the amount of carbon within the existing pile. Also determine how much carbon would be added to the completed Stage II pile from existing carbon sources, i.e., that carbon found in tailings, in the remnants of mill reagents, and the biosolids from the Cannery.
- Determine the need for supplemental carbon addition to ensure that sulfate reduction processes continue to occur at a rate sufficient to produce water quality that is comparable to that water in the existing saturated zone. This amount is the difference between what is required and what would be available when the Stage II pile is completed. Types of carbon that may be available in the pile after completion of stage II include carbon added as process reagents in the mill, residual amounts of added biosolids, carbon contained in the original ore material, and soluble carbon formed through decomposition of vegetation established on the pile.
- If supplemental carbon is needed, determine the most suitable form of carbon to be used. Types of carbon that could be considered include a liquid form that would be dispensed periodically over time as the volume of pore water gets displaced, such as that deployed through injection wells or a type of irrigation system; or a solid form that could be added as

the pile is developed or just prior to cap placement, such as bio-solids, a wood product, or coal. Geotechnical stability considerations would influence the form of carbon used.

Monument Values. Alternative C addresses this significant issue by reducing the disturbed area within the Monument through:

- Elimination of a proposed quarry and associated access roads at the southern end of the lease area.
- Movement of the southern half of the proposed reclamation materials storage area outside of the Monument to the northeast corner just outside the current lease area.

Figure 2-6 and Figure 2-7 show the area within the Monument proposed to be eliminated from the Proposed Action and the area outside the Monument intended for a new reclamation storage area. The southern boundary of the lease area would move north approximately 1,480 feet.

The additional tailings placement footprint would occupy approximately 40 of the proposed 67 acre expanded lease area. The remaining 27 acres would be used for a quarry, borrow source, materials storage, and stormwater pond infrastructure needs, as well as for potential future long-term tailings disposal needs if additional ore reserves are located.

The East Ridge Expansion of the tailings pile would include:

- Expansion of the existing Pit 5 quarry to provide construction materials for infrastructure development and construction within the tailings disposal area and eventually, the placement of tailings.
- Development of a new quarry at the south end of the new lease boundary.
- Construction of a new water management pond system. Installation of surface water and groundwater controls and diversions.
- Use of existing Containment Pond No. 6 for containment and storage of sludge materials and eventually, the placement of tailings.
- Development of a storage area for excavated reclamation materials (topsoil and organics).
- Development of borrow areas for infrastructure development and reclamation materials storage.

Figure 2-6 Alternative C - Existing Tailings Facility Lease Area, Present, and Projected Footprints of Tailings Placement

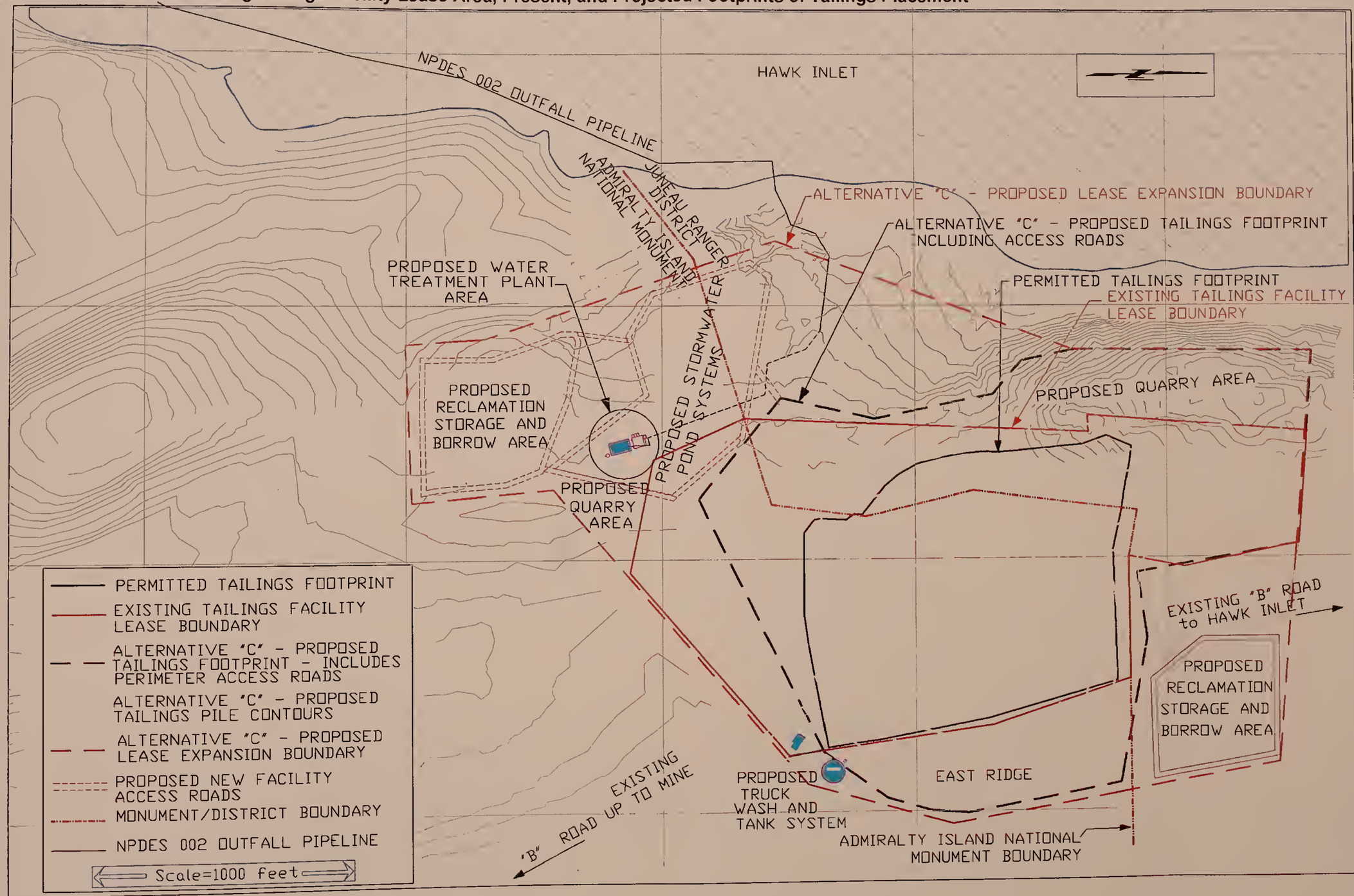
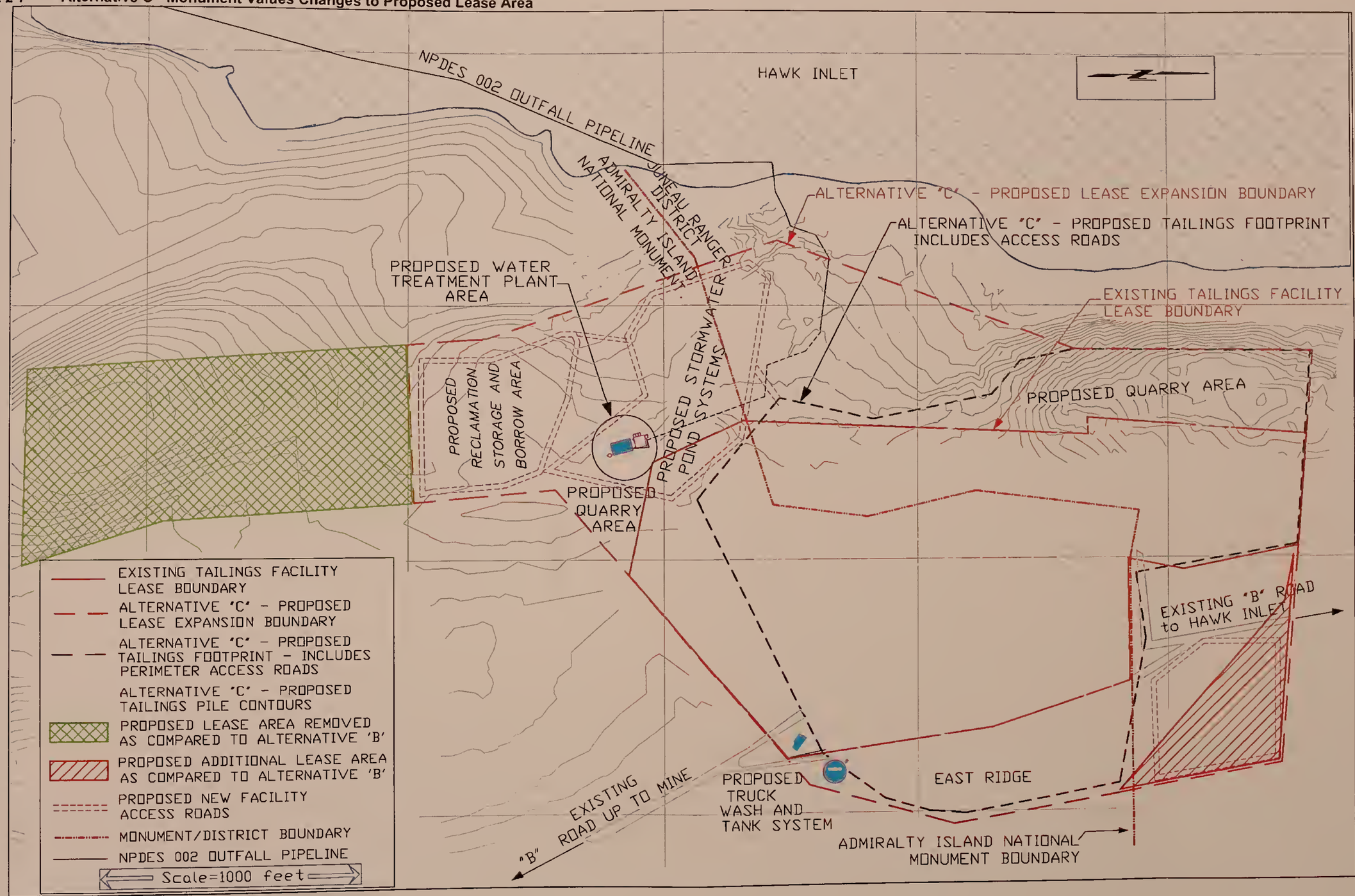


Figure 2-7 Alternative C - Monument Values Changes to Proposed Lease Area



2.4.4 Alternative D - Continuous Carbonate Addition and Expanded Boundary as needed for Additional Volume

Alternative D would modify the general plan of operations to require the addition of carbonate (limestone) into the entire volume of new tailings placed on the pile. The volume of carbonate necessary to neutralize the tailings would expand the footprint of the tailings pile to 81 acres. The purpose of this alternative is to consider an alternate method of increasing the neutralizing potential of the tailings pile beyond what is expected in the proposed action.

Water Quality. Alternative D would require mixing limestone into the tailings on an on-going basis, either in the mill or in the process of putting the tailings on the pile. The addition of the carbonate would increase the buffering capacity of the pile, or its ability to neutralize acid. About 2 million tons, or 1½ million cubic yards, of limestone would be needed to sufficiently neutralize the tailings. The addition of carbonate to buffer acidity has been used for a long time and the amounts of limestone needed to provide a given amount of buffering capacity is well known.

The addition of limestone would increase the volume of the pile and require expanding the tailings facility lease area 116 acres, increasing the total lease area to 172 acres. Capping requirements would remain as they are under the GPO. Table 2-3 provides an overview for comparing alternatives physical aspects.

This alternative would also require a structure of about 18,000 square feet for dry storage of limestone and equipment for mixing the limestone into the tailings. In addition to the increase of the size of the tailings pile, the dry storage area and mixing equipment would require an additional 1 or 2 acre increase in the footprint at the mill or tailings site.

Monument Values. The representation in Figure 2-8 provides the best fit for this alternative while still addressing the issues. There are a limited number of areas that the tailings pile can expand into while still addressing other resource and topographical concerns.

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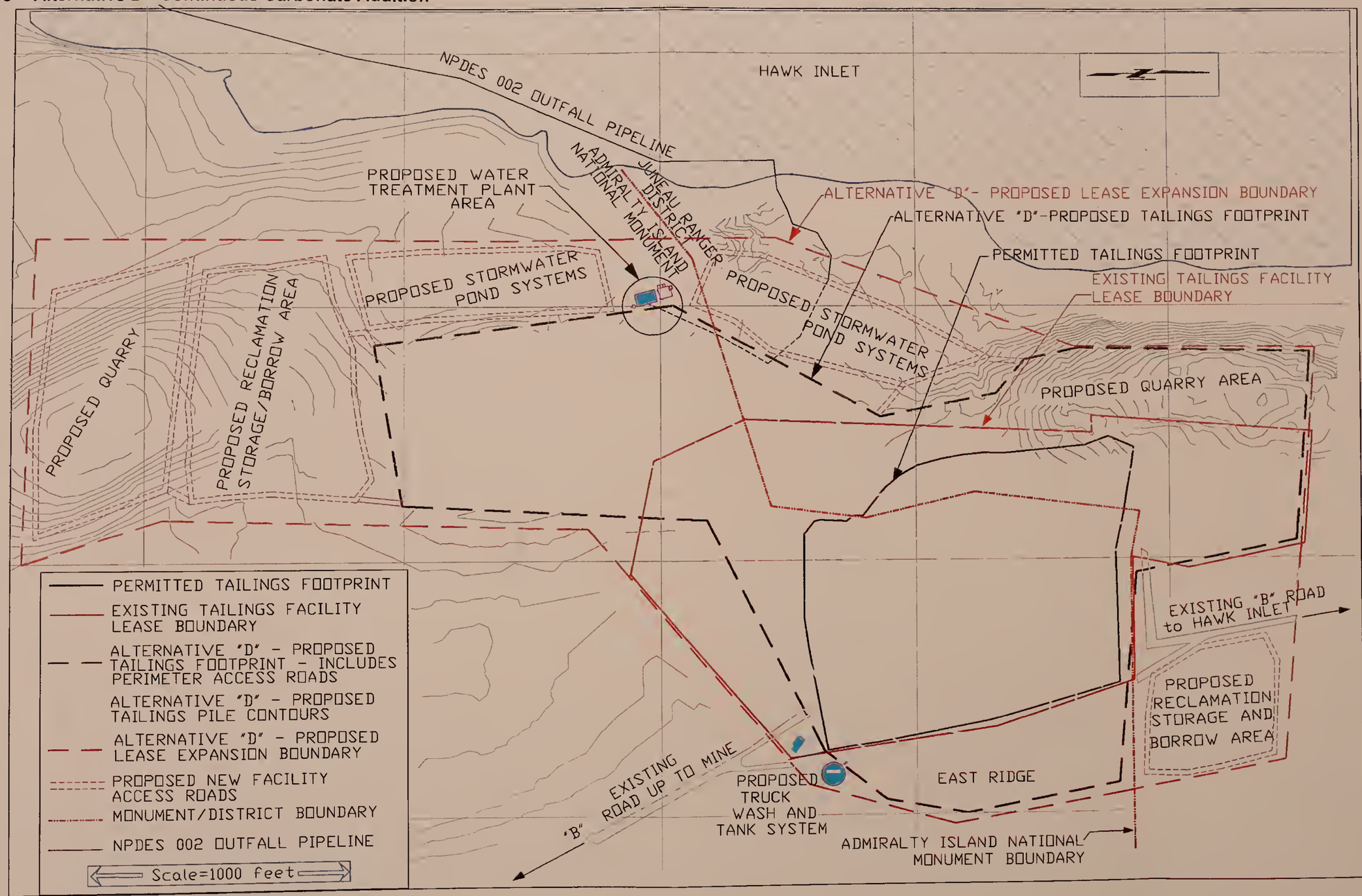
Figure 2-8 Alternative D - Continuous Carbonate Addition



2.5 Comparison of Alternatives

In Chapter 4, the environmental consequences of each alternative on water quality, monument values, and other issues identified during scoping are described in detail. To the extent possible, those consequences are quantified and objectively described. This section compares those impacts in summary form. Readers are urged to view the full analyses of impacts in Chapter 4. The terms *significant, minor,* and *negligible,* are used in the following comparisons and in Chapter 4. These terms are explained below, in the introduction of Chapter 4, and in the glossary. The thresholds for what represents a negligible, minor, or significant impact differ for each resource. For example, significance of water quality impacts is determined by comparison to AWQS; significance of impacts to wetlands is evaluated by the area of low, medium, or high value wetlands that would be filled. Two alternatives can have different levels of consequence, for example differing levels of wetlands filled, but still both be evaluated as having minor levels of impacts in the context of the project and study area.

Impacts are defined as "those changes to the existing environment that have either a beneficial or adverse consequence as a result of project construction, operation, and maintenance." (40 CFR 1508.8) Impacts are described in terms of frequency, duration, general scope and/or size, and intensity.

The combinations of frequency, duration, scope/size, and intensity of identified adverse impacts are described as follows:

None – (no change) No impacts are anticipated when subject resources are not present or activities are not expected to affect those resources that are present.

Negligible – Impacts on subject resources may occur as a result of project activities, but are not measurable.

Minor – Impacts that are less than significant and do not require avoidance or minimization to mitigate that effect.

Significant – as used in NEPA, is determined by considering the context in which the action will occur and the intensity of the action (40 CFR 1508.27).

2.5.1 Water Quality

The potential impacts to water quality are discussed in Section 4.5 and Appendix A. See Figure 3-9 for a description of watersheds and drainage areas. Summarized below are the effects of each alternative.

Under all alternatives including Alternative A, No Action, water would continue to be treated during operations using existing treatment processes. During mine closure and post-closure periods, water would continue to be treated using existing treatment processes until such time that effluent quality is such that these treatment processes are not required in order to meet discharge requirements. At that time and depending on actual effluent quality, KGCMC would discharge water one of the following ways, in decreasing order of preference:

(1) Discharge into nearby surface or groundwater (a) without dilution water from pile runoff and groundwater, or (b) with such dilution. This discharge would meet fresh water quality-based effluent limits;

(2) Discharge directly into Hawk Inlet. This discharge would meet marine water quality–based effluent limits with a potential dilution factor from a mixing zone; or

(3) Continue to discharge into Hawk Inlet through a submerged diffuser using technology-based limits.

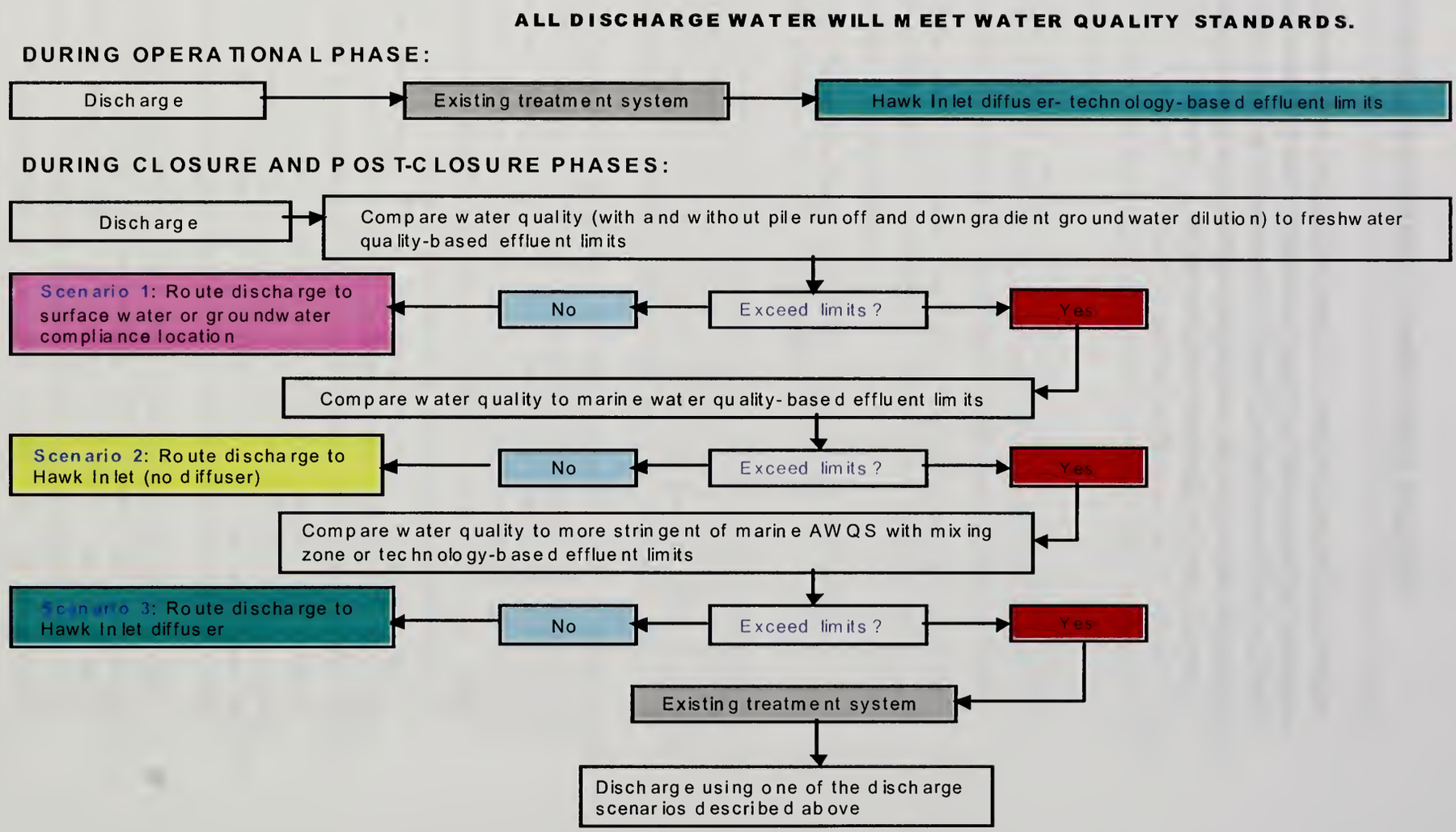
Any of these discharge/compliance scenarios would be conducted under a re-issued NPDES permit with any pertinent mixing zone authorized by ADEC. Figure 2-9 summarizes the discharge decision logic used to determine which discharge scenario to use during the closure and post-closure period.

The water quality model developed for each alternative predicts effluent water quality without the use of the existing treatment processes, beginning at the onset of closure (completion of the pile cover) and continuing into the post-closure period. The model results are compared to AWQS for the discharge scenarios described above and shown in Figure 2-1 and Figure 2-9. Under discharge scenario 1a, the predicted water quality from the underdrain is compared to freshwater AWQS. . Discharge scenario 1b compares the predicted water quality from the underdrain diluted with surface runoff from the pile and the downgradient groundwater system prior to freshwater AWQS. The model results are also compared to AWQS for marine water using a mixing zone having a dilution ratio of 50:1 and no diffuser, managed under discharge scenario 2 above. The 50:1 dilution ratio was assumed based on the 170:1 dilution ratio authorized by ADEC in the existing discharge permit.

The water quality predicted by the model is also compared to allowable technology-based loads under the existing NPDES permit for the instance of a future discharge through a diffuser to Hawk Inlet. This is managed under discharge scenario 3 as described above. Note: even though the State has authorized a mixing zone having a dilution ratio of 170:1 for the existing discharge permit, the technology-based limits contained in the existing permit do not reflect this dilution. These comparisons are made so that water quality

impacts can be assessed, and a determination made as to when the existing treatment system would no longer be required. The potential impacts to water quality are discussed in Section 4.5 and Appendix A. See Figure 3-9 for a description of watersheds and drainage areas. Summarized below, following Figure 2-9, are the effects of each alternative.

Figure 2-9 Flow Chart for discharge/compliance scenario selection



Alternative A

Results from the water quality model for Alternative A are shown in Figure 4-5 and Table 4-2. Results indicate that exceedances to fresh water AWQS (discharge scenario 1(a) without dilution) for sulfate and antimony are initially predicted for underdrain water. After 25 years, antimony levels should have dropped below AWQS, but selenium may increase and could exceed AWQS. After 200 years, sulfate should decline below AWQS; however, zinc concentrations are predicted to have risen above AWQS. After 500 years, cadmium levels may be above AWQS. Without treatment, none of these substances exceeds AWQS initially at the compliance point where underdrain flow mixes with surface water and groundwater (discharge scenario 1(b) with dilution), but selenium, zinc and cadmium levels are predicted to have exceeded AWQS after 100, 350, and 1000 years, respectively. Selenium levels are predicted to have fallen back below AWQS after 350 years. These predicted exceedances of AWQS under discharge scenario 1 may impair existing protected water use classes if discharged without treatment. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Model results compared to AWQS for marine water (discharge scenario 2) show there are no exceedances. The predicted load of metals was compared to the currently allowable loads under the existing discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than one percent of allowable loads for Alternative A for all metals in the permit.

Effects to water quality in the Hawk Inlet drainage would be considered significant if tailings effluent is discharged (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be negligible adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater or marine water.

Alternative B

Results from the water quality model for Alternative B are shown in Figure 4-6 and Table 4-3. Results are similar to those for Alternative A, indicating that sulfate and antimony would initially exceed fresh water AWQS in the underdrain flow without dilution, (discharge scenario 1(a)). After 25 years, increased selenium levels are predicted to have exceeded AWQS in the

underdrain. After 100 years, cadmium and zinc levels are predicted to have exceeded AWQS. Antimony and sulfate concentrations are expected to have dropped below AWQS after 200 years, followed by selenium after 500 years. Without treatment, only sulfate would initially exceed fresh water AWQS with dilution under discharge scenario 1(b), but selenium, zinc and cadmium are expected to be in exceedence of fresh water AWQS at 25, 200 and 500 years, respectively. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Model results for Alternative B compared to AWQS for marine water (discharge scenario 2) show there are no exceedances. The predicted load of metals was compared to the currently allowable loads under the NPDES discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than 1 percent of allowable loads for Alternative B for all metals in the permit.

As with Alternative A, effects to water quality in the Hawk Inlet drainage would be considered significant if tailings effluent is discharged (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be negligible adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater or marine water.

Alternative C

Summary results from the water quality model for Alternative C are shown in Figure 4-7 and Table 4-4. Results for Alternative C reflect the fundamental difference in long-term chemistry that would result from the addition of carbon to the tailings pile. As with Alternatives A and B, initially water in the underdrains without dilution (discharge scenario 1(a)) could exceed fresh water AWQS for sulfate and antimony. Sulfate concentration would decrease after 200 years to below fresh water AWQS. Elevated zinc and selenium would not occur in the underdrain water because on-going sulfate reduction tends to remove these constituents. Antimony, on the other hand, is not affected by sulfate reduction, and may increase as a result of biological reduction. The elevated antimony concentration predicted by the model is likely to be removed from solution when the water from the underdrain contacts the air causing iron and manganese compounds to chemically precipitate, adsorb antimony, and settle from solution. All of these substances are expected to meet fresh water AWQS with dilution (discharge scenario

1(b)) at the compliance point except for sulfate. Sulfate, at the compliance point using dilution, is marginally above fresh water AWQS for the first 50 to 100 years (without treatment). KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Results of the water quality model for Alternative C compared to marine water AWQS (discharge scenario 2) show there are no exceedances. The predicted load of metals was compared to the loads currently allowable under the NPDES discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than 0.1 percent of allowable loads for Alternative C for all metals in the permit.

Effects to water quality in the Hawk Inlet drainage are considered *minor* (compared to *significant* for Alternatives A and B) for the case where tailings effluent is discharged directly (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to receiving waters (discharge scenario 1). If water treatment were continued in perpetuity, there would be negligible adverse effects to the receiving surface water or groundwater. There would be negligible adverse effects to marine water for the case where tailings effluent is discharged directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects for the case where tailings effluent is discharged through a diffuser into Hawk Inlet (discharge scenario 3).

Alternative D

Results from the water quality model for Alternative D are shown in Figure 4-8 and Table 4-5. Water quality for Alternative D is similar to that of Alternative B, with concentrations of sulfate and metals slightly higher due to the greater area of the pile. In the underdrain (without dilution, discharge scenario 1(a)), sulfate and antimony may initially exceed AWQS followed by AWQS exceedances of selenium, zinc, and cadmium after 25, 50, and 100 years, respectively. At the compliance point with dilution (discharge scenario 1(b)), sulfate and antimony initially exceed AWQS, but are predicted to be below AWQS after 200 and 25 years, respectively. Selenium, zinc, and cadmium are predicted to be above AWQS after 25, 200, and 500 years, respectively. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Results of the water quality model for Alternative D compared to marine water AWQS (discharge scenario 2) show there are no exceedances. The predicted load of metals was compared to the loads currently allowable under the NPDES discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than 2 percent of allowable loads for Alternative D for all metals in the permit.

As with Alternatives A and B, effects to water quality in the Hawk Inlet drainage are considered significant for the case where tailings effluent is discharged directly (without treatment) to surface water or groundwater without dilution (discharge scenario 1(a)), or with dilution (discharge scenario 1(b)) (without treatment) with surface water or groundwater prior to discharge to receiving waters (discharge scenario 1). Effects to marine water would be negligible, the same as Alternative A or B, for the case where effluent is discharged directly to Hawk Inlet (without treatment or diffuser). There would be negligible adverse effects for the case where tailings effluent is discharged through a diffuser into Hawk Inlet - the same as under Alternatives A, B, and C. If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater, or marine water.

2.5.2 Monument Values

The main criterion for comparing effects to monument values is the numbers of acres leased within the Monument and subject to potential disturbance. Alternative A currently leases 38 acres in the Monument and has a tailings footprint in the Monument of 20 acres and would increase to 25 acres. Alternative B would lease 90 acres in the Monument with the tailings footprint occupying 28 of those acres. Alternative C would lease 68 acres in the Monument with the tailings footprint occupying 36 of those acres. Alternative D would lease 115 acres in the Monument with the tailings facility occupying 56 of those acres.

Table 2-3 below presents a comparison of acreages.

2.5.3 Other Issues

During scoping a number of other issues were identified. The effects of each alternative are summarized in Table 2-3 below.

Table 2-3 Comparison of Alternatives

Element	Alternative A	Alternative B	Alternative C	Alternative D
Physical Components				
Tailings Facility Lease Area after expansion (acres)	56	140	123	172
Tailings Facility Lease Area boundaries expansion (acres)	0	84	67	116
Total Tailings Footprint Area (acres)	29	61	62	81
Total Disturbed Area (estimated acres)	54	125	110	162
Tailings Placed Underground				
Tons	0	7,333,000* whole tailings (includes 733,000 cement)	7,333,000* whole tailings (includes 733,000 cement)	7,333,000* whole tailings (includes 733,000 cement)
Cubic Yards	0	4,073,889* (includes 852,326 cement)	4,073,889* (includes 852,326 cement)	4,073,889* (includes 852,326 cement)
Tailings Placed on Surface				
Tons	0	6,000,000* whole tailings	6,000,000* whole tailings	6,000,000* whole tailings
Cubic Yards	0	3,333,333* whole tailings	3,333,333* whole tailings	3,333,333* whole tailings
Amendment Quantity (tons)	0	0*	None to 60,000* carbon	2,034,000* limestone
Amendment Quantity (cu yd)	0	0*	None to 44,776 carbon	1,517,910 limestone
Height of Tailings Pile Above Existing Ground Level (feet)	80	160	160	160
Maximum Tailings Pile Elevation Above Sea Level (feet)	250	330	330	330
Roads				
Miles of New Road	0.16	1.93	1.19	4.30
Miles of Road Obliterated	0.12	0.63	0.94	0.94

Table 2-3 Comparison of Alternatives

Element		Alternative A	Alternative B	Alternative C	Alternative D
Total Miles (excluding construction roads on pile)		1.35	2.83	2.82	4.52
Water Treatment Plant Location		Remains in place	Moved	Moved	Moved
Truck Wash Station Location		Moved	Moved	Moved	Moved
Significant Issues – Water Quality					
Ground Water	w/o treatment	S	S	M	S
	w/ treatment	N	N	N	N
Surface Water	w/o treatment	S	S	M	S
	w/ treatment	N	N	N	N
Marine Waters w/o Mixing Zone	w/o treatment	N	N	N	N
	w/ treatment	N	N	N	N
Marine Waters w/ Mixing Zone	w/o treatment	N	N	N	N
	w/ treatment	N	N	N	N
Significant Issues – Monument Values					
Total Lease Area After Expansion (acres)		56	140	123	172
Lease Boundaries Expansion Area Only (acres)		0	84	67	116
In Monument		38	90	68	115
Outside Of Monument		18	50	55	57
Total Tailings Footprint (approximate acres)					
Total Tailings Footprint Area (acres)		29	61	62	81
In Monument		25	28	36	56
Outside of Monument		4	33	26	25
Other Issues					
Air Quality		N	N	N	N

Table 2-3 Comparison of Alternatives

Element	Alternative A	Alternative B	Alternative C	Alternative D
Visual Quality	M	M	M	M
Marine Water Quality	N	N	N	N
Wetlands Impacts – (Though acreage of filled wetlands differs, all are evaluated as minor in the context of the project and study area)	M 0 ac. beyond those already permitted	M 22 ac. Low Value	M 10 ac. Low Value	M 42 ac Low Value / 0.7 ac. Medium Value
Vegetation	M	M 71 ac.	M 56 ac.	M 108 ac.
Wildlife				
Terrestrial Mammals	N	N	N	N
Birds	N	N	N	N
Marine Mammals	None	None	None	None
T&E Species	None	None	None	None
Marine Life	N	N	N	N
Essential Fish Habitat	N	N	N	N
Heritage Resources	None	None	None	None
Subsistence	N	N	N	N
Recreation	N	N	N	N
Socioeconomic	M adverse	M positive	M positive	M adverse
Estimated Cost of Construction and Implementation	$ 0 ***	$ 10,000,000 – $ 20,000,000	$ 11,000,000 – $ 26,000,000	$ 75,000,000 – $ 280,000,000
Environmental Justice	None	None	None	None
Cumulative Impacts	N	N	N	N

Weight / Volume Conversions: cement = .86 t/yd^3, limestone/carbon = 1.34 t/yd^3
Whole Tailings = 1.8 t/yd^3
* Weights and volumes indicate value above currently permitted amount (2.1M yd^3, 3.78 M t.)
** Estimated placement volumes based on currently permitted volumes at tailings
*** Baseline for comparison of estimated increased costs
S = Significant, M = Minor, N = Negligible

2.6 Alternatives Considered and Eliminated from Detailed Study in the EIS

During the course of scoping and subsequent development of this EIS, a number of alternative actions were considered and screened against the following criteria:

- Does the alternative action meet the purposes and need (Section 1);
- Is the action better addressed through another alternative; and
- Would the action be likely to cause greater adverse impacts than other alternatives?

Alternatives that were screened-out include the addition of a carbonate veneer to the pile, the location of a second pile at a different site, and several alternatives involving the use of pyrite circuits. This section describes these alternatives in summary fashion and the reasons for their elimination from detailed study in the EIS. It is excerpted from the Alternative Screening Document (MBJ, 2002) that is in the planning record.

2.6.1 Carbonate Veneer Alternative

This alternative would have been similar to the use of a carbon veneer except that the veneer would have been formed by a carbonate additive such as limestone, rather than carbon. Enough carbonate would have been mixed into the final stages of the pile so the top layer of tailing (the area most exposed to oxygen and water) would no longer generate acid.

While the addition of a carbonate veneer addresses the problem of acid generation, it does not do so as effectively as a full carbonate addition and does not address the potential for metals leaching as effectively as carbon addition. The addition of carbon, on the other hand, addresses both these concerns. Also, the desired results require a much smaller volume of carbon than limestone. In other words, a carbon addition, as proposed in Alternative C, would be both more efficient and would require less space.

2.6.2 Alternate Tailings Disposal Site

The possibility of separate tailings disposal areas outside the Monument was also considered. Much of the terrain around the mine, however, is steeply sloping or is wetlands—both less suitable for tailings disposal. Although a possible site was identified at mile 2.2 on the A-road, it was determined that construction would substantially increase the impacts to wetlands, wildlife, and the potential for impacts to water quality.

2.6.3 Pyrite Circuit Scenarios / Pyrite Reduction Alternatives

Also considered at length was a collection of alternatives based on the use of a *pyrite circuit* to remove a portion of the pyrites from the tailings. The main difference among the various pyrite circuit alternatives is the method for storing and disposing of the highly reactive pyrite concentrate. While removing the pyrite concentrate from the tailings would lower the potential for acid generation, it would not address the possibility of metals leaching from the tailings pile—which has been identified as of greater concern than acid rock drainage (ARD). Each of these alternatives was eliminated from further consideration because of the technical difficulties of containing and disposing of the highly reactive and potentially combustible pyrite concentrate (Nineteman, 1978; Reimers and Pomproy, 1988; Reimers and Franke, 1991; Pearse, 1980) combined with their various potentials for acid generation and/or metals leaching and difficulties with reclamation.

A brief discussion of the pyrite circuit alternatives is presented in this section. A complete discussion is presented in Appendix G.

Pyrite Alternative 1: A pyrite circuit with all pyrite concentrate stored in containers on the pile lease area. The pyrite plant would be located beside the Concentrator at the 920 mine site adjoining the existing facilities. For a nominal rate of 1600 tpd the pyrite plant would include:

- Pyrite rougher conditioner tanks
- Pyrite rougher flotation circuit
- Pyrite cleaner flotation circuit
- Pyrite final tails stock tank
- Pyrite thickener
- Pyrite concentrate stock tank

The pyrite circuit is substantial and would have to be located in a highly congested area at the mill site. A sulfuric acid storage area would also be needed at the mill site, which is not shown in the drawings. The conceptual pyrite storage facility would need a large flat area to allow a footprint of 87 acres.

> This option was eliminated from further consideration because of the difficulty of reclamation of the containment cells, technical feasibility (integrity of long term repository), and high costs associated with its development.

Pyrite Alternative 2: This alternative is the same as Pyrite Alternative 1, except the total volume of pyrite concentrate produced by the pyrite circuit (PRC) would be placed back into the mine. This alternative would also require

a pyrite concentration storage facility to use in the event that the underground mine was not able to accept the concentrate at the same rate it was produced. The size of this facility would be approximately one acre.

> This option was eliminated from further consideration due to safety concerns and damage to Monument values from the high risk for mine drainage violating Alaska Water Quality Standards for zinc, copper, cadmium, lead, and silver and pH.

Pyrite Alternative 3: This alternative is the same as Pyrite Alternative 1, except a portion of the pyrite concentrate would be stored in mine with cement and carbonate needed for full buffering, and the remainder stored in containers on the pile. In addition to the pyrite concentration plant required for Pyrite Alternative 1, this alternative would also require a carbonate dry storage area, carbonate/concentrate mixing equipment, and an amended concentrate short-term storage area. This could result in a 1-2 acre increased footprint at the mill site.

> This option was eliminated from further consideration because of the high potential for mine drainage containing metal leachate, reclamation difficulties, the technical difficulty of developing suitable containment facilities and a suitable method of blending the concentrate and the carbonate material, and the high costs.

Pyrite Alternative 4: This alternative is the same as Pyrite Alternative 1, except the pyrite concentrate would be shipped off-island. The material would either be shipped to a hazardous waste landfill, or sold to a buyer that would process the concentrate for the remaining metal value.

> Because there is no available site to ship the pyrite concentrate to, this option was eliminated from further consideration.

Pyrite Alternative 5: This alternative differs from Pyrite Alternative 1 in that only a portion of the tailings would be processed in the pyrite reduction circuit. Approximately 53.4 percent of whole tailings would be processed through the pyrite circuit, amended to net neutralization potential (NNP) of 0, and placed underground. The remaining whole tailings would be blended in some fashion with the depyritized tailings, be amended with limestone and placed in the tailings expansion. The resultant mixture of whole tailings, depyritized tailings, and limestone would also have an NNP of 0. The tailings facility would have to be expanded to 96.5 acres to accommodate the additional volume of limestone in this alternative.

> This option was eliminated from further consideration due to the increased visual impact, reclamation difficulties, and the

technical difficulty of developing a suitable method of blending the concentrate and the carbonate material, and the high costs.

Pyrite Alternative 6: Only a portion of the tailings would be processed in the pyrite reduction circuit in this alternative. Unlike Pyrite Alternative 5, the pyrite concentrate would not be fully amended with limestone to achieve a NNP of 0. Instead, the target NNP for the backfilled concentrate would be the same level as currently found in the whole tailings that are currently being backfilled in the mine. The remaining whole tailings would be blended with the depyritized tailings and would be placed at the surface in the tailings expansion. The resultant mixture of whole tailings and depyritized tailings would have an NNP of -16. The tailings facility would be expanded to 90.3 acres to accommodate the additional volume of limestone.

This alternative was not carried forward due to potential mine drainage containing ARD and metals and the large increase to the size of the pile, the high risk for reclamation due to the difficulties in creating suitable containment facilities for the concentrate on the pile, the visual impacts of doubling the size of the pile, the high risk of technical feasibility due to developing a suitable method of adequately blending the concentrate with the carbonate material, and the high risk for economic feasibility due to the costs of developing a pyrite circuit and carbonate addition.

Chapter 3
Affected Environment

3 Affected Environment

3.1 Location

3.1.1 Description of the Proposed Project Study Area

The Greens Creek Mine is an underground zinc/silver mine, lying partially within the Admiralty National Monument on northern Admiralty Island, Alaska. This property is located approximately 18 miles southwest of the city of Juneau.

The proposed project involves an expansion of the existing tailings pile. This EIS deals with the aspects of the environment affected and potentially affected by the proposed project. Those aspects include the following:

- Land on which tailings and related facilities are or may be placed, including portions of Admiralty Island National Monument, and the geology and geochemistry of the project area;
- Climate of the project area;
- Air quality of the project area
- Wetlands that might be affected by the project;
- Vegetation that might be affected by the project;
- Freshwater systems that might be affected by water from the pile;

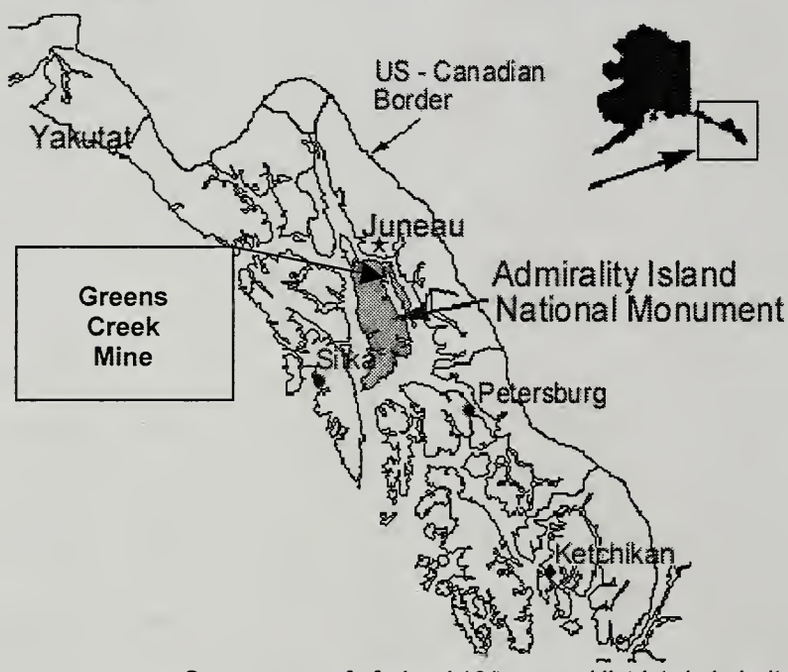
- Fish, invertebrates, and marine mammals that live in potentially affected waters;
- Wildlife found in the vicinity of the project; and
- Heritage resources, subsistence, recreation, and socioeconomic issues, i.e., the human environment.

As reflected by the identification of the significant issues, which include monument values, the greatest potential impacts from the project have to do with water and water quality. Because of that, there is a heavy emphasis on the complex interplay among geochemistry, hydrology, and the uses of water throughout this document. (EDE, 2002a; 2002b)

3.2 Land

The Greens Creek Mine facilities are located within the Greens Creek, Zinc Creek, Cannery Creek, Tributary and Fowler Creek watersheds. In addition to the leased land, approximately 15 acres of private land at the cannery at the Hawk Inlet Marine terminal have been used for the development of mine facilities.

Figure 3-1 Admiralty Island National Monument



Source: www.fs.fed.us/r10/tongass/districts/admiralty

Mine facilities are located in and adjacent to the Admiralty Island National Monument. The existing lease area for the tailings facility is 56 areas. Of this total lease area, 38 acres are in the Monument and 18 acres are not. The tailings footprint is currently permitted for 29 acres. Of this

total permitted footprint area, 25 acres are in the Monument and 4acres are not.

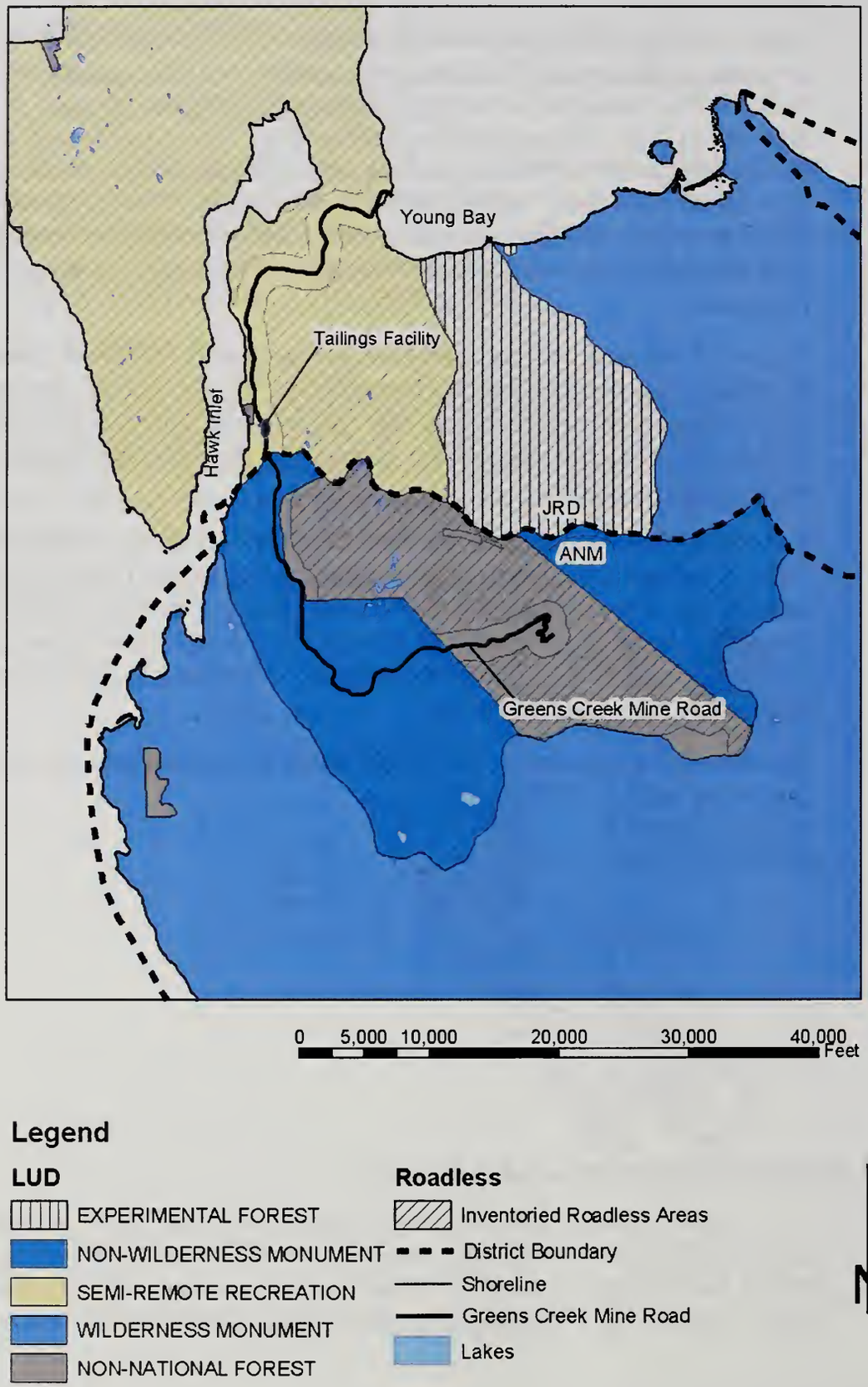
Current mining activity produces an average of 555,000 tons of dry tailings per year. A little over half of that amount is disposed of as underground backfill. The remainder, an average of about 270,000 tons per year, is disposed of in the Cannery Muskeg tailings pile. The current leased area for the tailings facility is 56 acres, and the current permit allows for tailings disposal on 29 of those acres. As described in Chapter 2, the proposed action would involve an 84-acre expansion of the tailings facility lease boundary. Alternatives C and D would involve expansions of 67 and 116 acres, respectively.

Figure 3-2 below shows the Land Use Designations (LUDs) and Inventoried Roadless Areas surrounding the Greens Creek Project. Though the area surrounding the mine is an inventoried roadless area, the mine itself and associated roads, facilities, and the tailings pile, including the tailings expansion area are not.

The Young Bay landing dock, the road from the dock to the cannery site (offices, cafeteria, floatplane dock and ore loading facility), the road from the cannery site to the tailings pile, the tailings pile itself, and part of the road to the mine is in the semi-remote recreation LUD. South of the tailings pile, the road to the mine crosses into Non-wilderness monument LUD and then crosses into Non-national forest.

No new roads connected to this project would be constructed outside of the immediate tailings pile area.

Figure 3-2 Land Use Designation / Inventoried Roadless Areas



USDA, FS, 2003, TNF GIS database

3.3 Climate

3.3.1 Regional Hydrology

The most significant regional hydrologic feature of the area, which is characterized as a temperate rain forest, is the amount of precipitation, both in the form of rain and snow. Although precipitation levels in Southeast Alaska are generally high, some areas get more precipitation than others, and the amounts vary widely depending on the particular features of the terrain. The regional annual precipitation at sites near sea level is between 40 inches (Angoon) and 225 inches (Port Walter). (EDE, 2002A)

3.3.2 Local Hydrology

The dominating influence on the local hydrology at the tailings site, as with the regional hydrology, is the large amount of precipitation. Since 1997, an automated monitoring system has collected data on the amount of precipitation at the tailings site. Between 1997 and 2000, the average annual precipitation at the site was 53.0 inches. Before the automated monitoring system, the company measured and manually recorded maximum and minimum daily and monthly totals. Table 3-1 shows monthly and annual totals for the four-year period of 1997 through 2000.

The precipitation levels recorded at the tailings site are consistent with other meteorological measurements in the general area. For example, the National Weather Service Climate Database reports that Angoon, on the western side of Admiralty Island, has a 40-year average annual precipitation of 42.2 inches. At the Juneau airport, annual precipitation has averaged 56.5 inches over a 51-year period of record. Auke Bay, north of Juneau, reports an annual average of 62.4 inches for a 37-year period of record. Given the surrounding records, it appears that, although the data from the tailings site are limited, they fit well with other sites within a 20 to 40 mile radius and at similar elevation (EDE, 2002a).

3.3.3 Temperature

The air temperature at the project site is heavily influenced by the coastal marine environment, which has a moderating effect on temperature extremes. The annual average temperature at the project site ranged was between 42° and 43° F between 1997 and 2000. The maximum and minimum one-hour average temperatures at the project site in 2000 were about 70° and 9°F, respectively.

Table 3-1 Monthly and Annual Precipitation at the Tailings Site, 1997 – 2000

Monthly and Annual Precipitation at the Tailings Site, 1997 - 2000

Station: NPDES Outfall 002 Parameter: Total Precipitation (Inches)
Year: 1997

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Maximum Daily Total	0.30	1.77	0.64	1.12	1.00	0.67	1.10	1.02	1.49	0.69	1.17	1.53	
Average Daily Total	0.05	0.19	0.10	0.12	0.06	0.07	0.20	0.13	0.18	0.14	0.10	0.03	
Monthly Total	**1.55**	**5.34**	**3.16**	**3.74**	**1.87**	**2.24**	**6.40**	**4.06**	**5.62**	**4.56**	**3.01**	**8.81**	**50.36**

Station: NPDES Outfall 002 Parameter: Total Precipitation (Inches)
Year: 1998

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Maximum Daily Total	0.54	0.33	0.82	0.30	0.61	0.64	0.85	1.23	1.03	2.89	0.49	0.85	
Average Daily Total	0.04	0.04	0.08	0.07	0.06	0.07	0.14	0.18	0.19	0.30	0.06	0.14	
Monthly Total	**1.48**	**1.29**	**2.60**	**2.23**	**2.16**	**2.34**	**4.38**	**5.78**	**5.75**	**9.33**	**1.98**	**4.40**	**43.72**

Station: NPDES Outfall 002 Parameter: Total Precipitation (Inches)
Year: 1999

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Maximum Daily Total	0.80	4.09	0.32	1.21	0.59	0.69	0.91	2.09	1.13	0.98	1.62	3.02	
Average Daily Total	0.16	0.27	0.05	0.18	0.15	0.08	0.13	0.21	0.26	0.28	0.18	0.28	
Monthly Total	**5.10**	**7.77**	**1.66**	**5.56**	**4.78**	**2.41**	**4.33**	**6.56**	**7.86**	**8.74**	**5.42**	**8.76**	**68.95**

Station: NPDES Outfall 002 Parameter: Total Precipitation (Inches)
Year: 2000

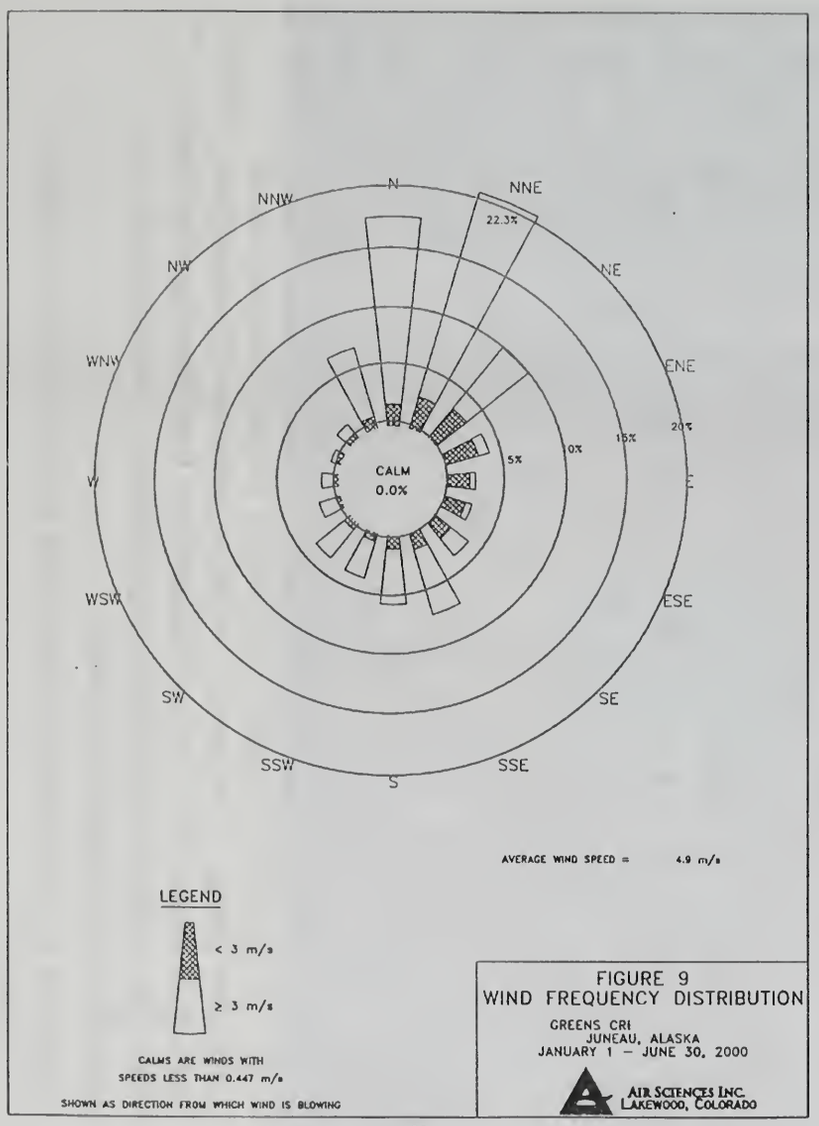
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Maximum Daily Total	1.17	0.20	0.60	0.81	0.64	0.70	0.94	0.82	1.25	1.00	0.81	1.51	
Average Daily Total	0.09	0.03	0.11	0.14	0.07	0.12	0.12	0.14	0.27	0.19	0.14	0.11	
Monthly Total	**3.02**	**0.94**	**.3.67**	**4.32**	**2.47**	**3.80**	**4.02**	**4.47**	**8.32**	**5.98**	**4.34**	**3.49**	**48.84**

Source: Kennecott Greens Creek Mining Company 2001

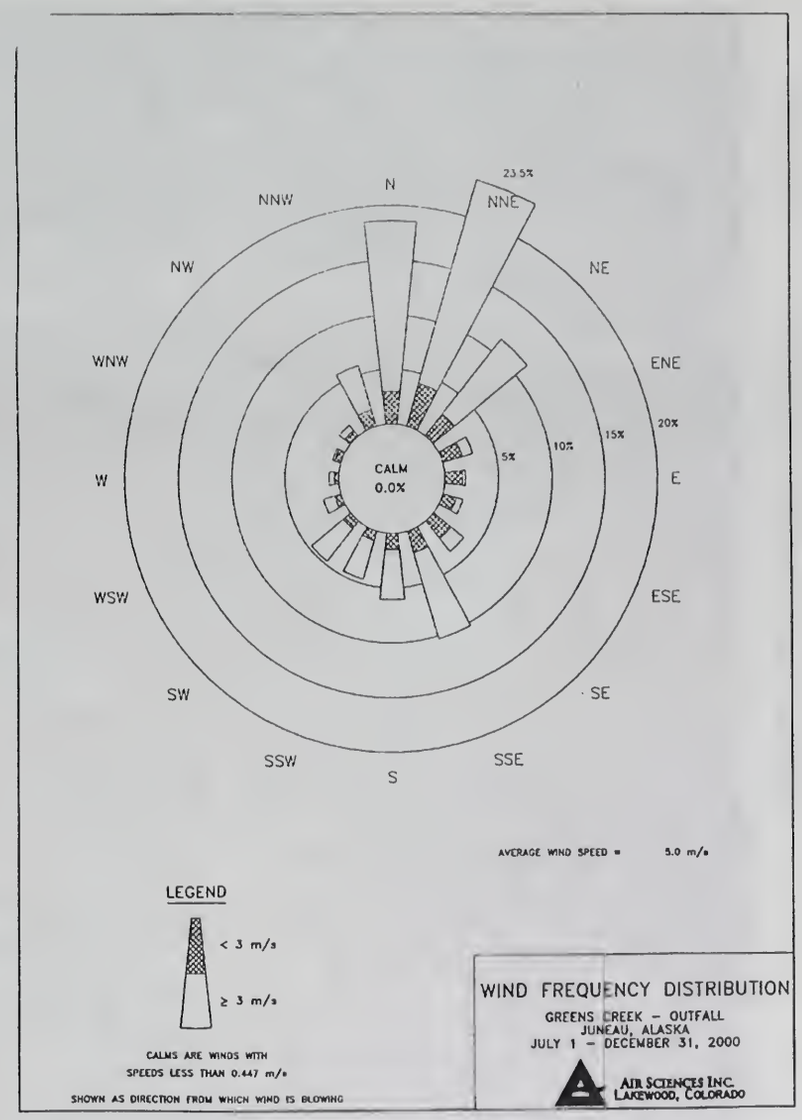
3.3.4 Wind

As with the level of precipitation, topography has a large influence on wind patterns. The terrain at the project site channels the wind, producing a flow predominately from the north-northeast, although strong winds from the south-Southeast are not uncommon. In 2000, the wind at the project site was from the north through northeast about 54 percent of the time and from the south-Southeast about 9 percent of the time. The highest wind speed recorded at the project site in 2000 was 17.2 meters per second (m/sec), or about 38 miles per hour (mph). The average wind speed was 5.0 m/sec, or about 11 mph. Figure 3-3 graphically represents wind conditions at the tailings site from January through June of 2000 and from July through December of 2000, respectively. (Air Sciences Inc, 2001).

Figure 3-3 **Wind Speed and Direction at Tailings Site**
January 1, 2000 through June 30, 2000



Wind Speed and Direction at Tailings Site
July 1, 2000 through December 31, 2000



3.4 Air Quality

Air quality in the vicinity is good. The nearest sources of atmospheric contaminants to the Greens Creek mine are in Juneau, 18 miles (29 km) northeast of the site. Sites are generally classified as to whether they attain or fail to attain air quality standards. The project site area has been designated as having attained such standards, based on available ambient data for all criteria pollutants.

The most recent ambient air quality monitoring in the area occurred from April 1, 1995 through March 31, 1996. Ambient concentrations of particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM_{10}) were measured. All measured results attained the applicable National and Alaska Ambient Air Quality Standards (AAQS).

The nearest location that has failed to attain (designated as *nonattainment*) air quality standards is the Mendenhall Valley area of Juneau, approximately 22 miles (34.5 km) north of the project site. The Mendenhall Valley area has been designated non attainment for PM_{10}. The nearest area designated as Prevention of Significant Deterioration (PSD) Class I is Denali National Park, approximately 621 miles (1,000 km) northwest of the project site. Air pollutant emissions from the existing Greens Creek facility do not have a significant impact at either location.

3.5 Visual Quality

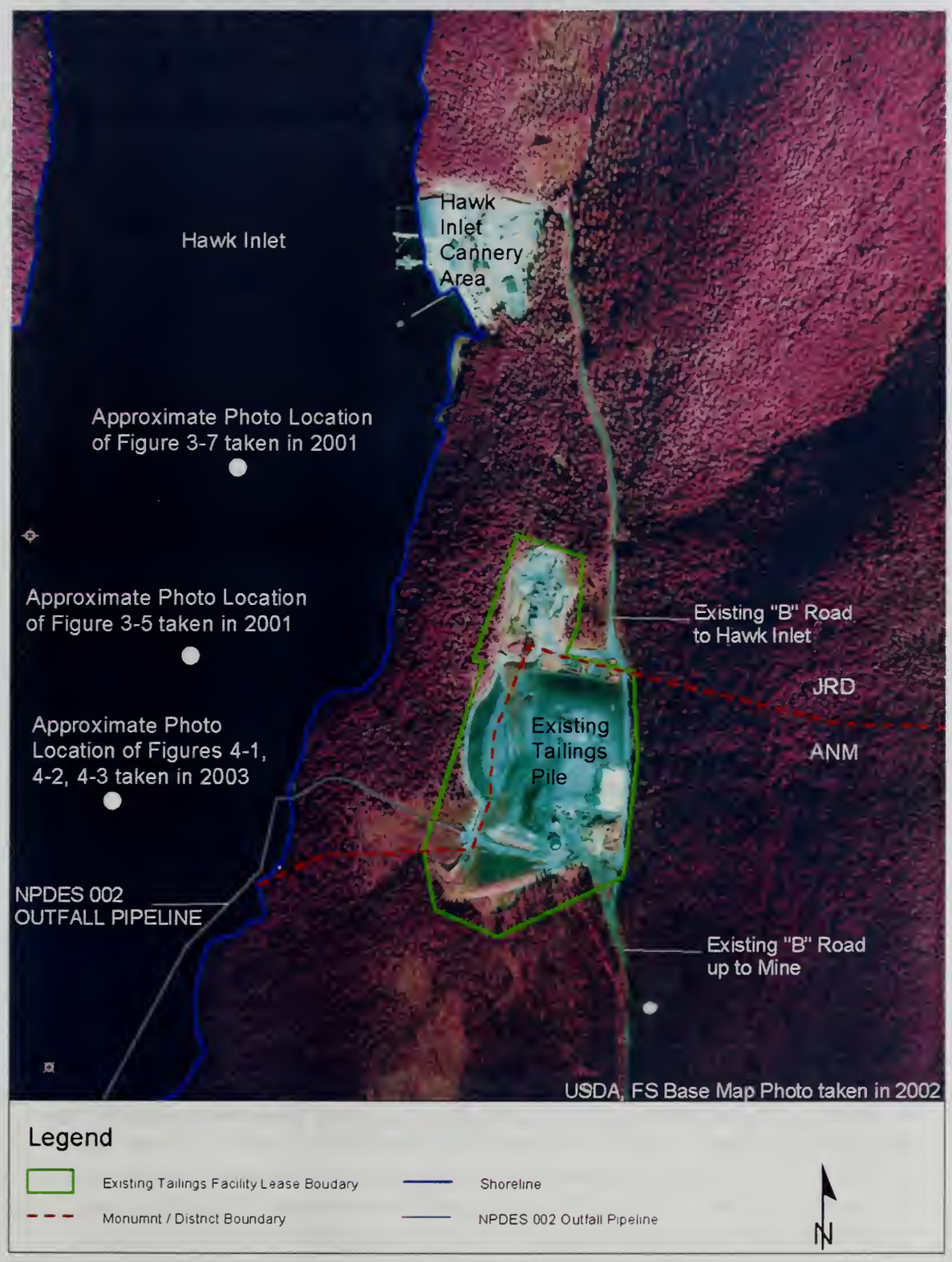
The Tongass Land and Resource Management Plan (Forest Plan) uses a combination of distance zone and Land Use Designation (LUD) to determine the adopted Visual Quality Objectives (VQO). Forest Plan identifies the project area as having a LUD of Non-Wilderness National Monument.

The project area is visible from the following Visual Priority Travel Routes & Use Areas listed in Appendix F of the Forest Plan. There are two small boat anchorages in Hawk Inlet, a small boat route in Hawk Inlet and the Alaska Marine Highway (AMH) route in Chatham Strait between Hoonah and Angoon passes approximately five miles from the mouth of Hawk Inlet.

VQOs are measurable standards that reflect four different degrees of acceptable change of the natural landscape based upon the importance of aesthetics. These allow a range of disturbance from Retention that does not allow any manipulation to Maximum Modification, which allows management activities to be evident.

Figure 3-4 is an infrared photo that shows the photo locations of Figure 3-5 and Figure 3-7.

Figure 3-4 Aerial View of Greens Creek Facilities



The project area is seen in the middleground from the small boat route and in the background from the boat anchorages and the AMH Ferry. During operations the adopted VQO is Maximum Modification. After closure, and for reclamation, the VQO is Retention (See Figure 3-5).

Figure 3-5 View of Hawk Inlet with tailings pile in background (2001)

Admiralty Island offers natural rugged scenery composed of high ridges with alpine tundra, steep cliffs with slides and avalanche tracks, mountain slopes densely covered with conifers, and lowlands of conifers, with pocket clearings of meadows, muskegs, and lakes. The study area includes the densely forested Greens Creek valley and the level plains and foothills along Hawk Inlet. High, forested ridges and numerous bodies of water, which form a repetitive pattern in the landscape, surround the mine.

The view of the tailings facility from the water at Hawk Inlet shows a marked horizontal line void of any vegetation (See Figure 3-5). The tailings pile itself is fairly low compared to the surrounding hills, a narrow band in the steep forested topography of Hawk Inlet. Its pale gray color, however, makes the top of the pile visible from the water against the deep green background of the coniferous forest

Figure 3-6 Aerial View of Tailings Pile, looking to the Southeast (2002)

Visual Absorption Capability. Visual absorption capability is the relative ability of a landscape to accept human alteration without loss of landscape character or scenic condition. It is a relative indicator of the potential difficulty, and thus the potential cost, of producing or maintaining acceptable degrees of scenic quality (pC-1, USDA, FS 1974). This section discusses visual absorption capability related to slope, vegetative cover, soils and geology.

The ability of this landscape to accept human alteration without a loss in landscape character is low to moderate, considering its dense, hemlock-spruce vegetation, varied slopes, and light-colored soils. The mine operation facilities at Hawk Inlet have already had a considerable impact on the landscape character of the study area (See Figure 3-7).

Existing Visual Condition (EVC) is an inventoried condition that represents the degree of change that has already occurred on the ground. It is measured in terms of condition Types I – VI, with Type I representing areas in which only ecological changes have taken place, to Type VI, representing areas of drastic landscape disturbance. EVC serves as a tool in issue identification, analysis of the management situation, estimation of effects of alternatives, monitoring, and as a historical record of the degree and amount of physical

alteration of the landscape. The project area is inventoried as a Type III EVC because the natural appearance of the landscape still remains dominant and the disturbance appears minor to the average forest visitor.

Figure 3-7 View of processing loading area from water (2001)

3.6 Oceanography

Hawk Inlet is a marine waterway chiseled into mineral-rich rock formations on northern Admiralty Island. The physical shape of this saltwater arm (described in Section 3.6.2, Topography and Bathymetry, below) off of Chatham Strait, in conjunction with large tides in the region produce strong currents which refresh nutrients within the inlet. The extent of seawater exchange together with freshwater nutrient inputs from rivers, streams and runoff support an ecosystem rich in marine life ranging from plankton to marine mammals.

This section describes the physical oceanographic characteristics of Hawk Inlet. Factors including tides, currents, and marine water quality are described using the best available information. Because the proposed project would increase the volume of mineral-laden water entering Hawk Inlet, a discussion of historical information on the amounts of some metals found in seafloor sediments at the outfall site and vicinity is included.

3.6.1 Physical Characteristics of Hawk Inlet

In order to understand the mixing and dilution of mine effluent as it enters a body of water, it is important to understand the physical characteristics of that water environment. Information on tides, depths, and other basic features are reported from National Oceanic and Atmospheric Administration nautical charts and tide records. Site-specific data are reported from scientific reports.

Several studies have been undertaken to define marine characteristics for Hawk Inlet. Studies completed prior to the start of mill operations are incorporated below based on the report by G. Andrews Environmental Associates (1996).

More recently, Greens Creek environmental staff and consultants have monitored water, sediment and vegetation within Hawk Inlet. Data from these studies are also presented in this description of baseline conditions (RTI, 1998). Data were collected throughout Hawk Inlet at sites referred in the text below.

3.6.2 Topography and Bathymetry

Hawk Inlet extends seven miles north from Chatham Strait and ends in a tidal mudflat estuary about 0.6 miles in diameter. Hawk Inlet consists of a narrow basin, partially separated from Chatham Strait by a relatively shallow sill that includes a delta at the mouth of Greens Creek. The narrow channel connecting the Inlet to Chatham Strait, located between the tip of the Greens Creek delta and the western shore of Hawk Inlet, has a minimum low tide depth of 35 feet.

The midchannel depth ranges from 35 feet at the sill, to 250 feet in the mid-portion of the Inlet. Near the mouth of the Inlet there is a large delta formed by glacial activity and by river borne sediments from Greens Creek.

3.6.3 Tides and Currents and Circulation

Hawk Inlet has regular, twice-daily tides. The large tidal variation (a maximum range from high to low) of about 25 feet, the shallow Greens Creek delta, and irregularities in the rocky shoreline strongly influence circulation patterns in the Inlet. Wind may have a strong effect on surface water movement, and freshwater flowing into the inlet further influences water flow speed and vertical mixing of water between depths.

On the flood tide, the surface 35-foot layer contains the bulk of the water transport entering the Inlet at the sill and is then flushed out on the ebb tide. Current velocities in Hawk Inlet are greatest at the 1,000-foot wide Greens Creek sill, reaching a maximum of about 70 cm/sec on the flood tide. The maximum flows at ebb tide are in the 40-cm/sec ranges in the vicinity of

NPDES Outfall 002 (Figure 3-8). Throughout the Inlet, current velocity decreases with depth. At 100 feet, currents are negligible—usually less than 10 percent of those at the surface.

Differences in flood and ebb tide circulation patterns have been observed. Flooding occurs predominantly along the eastern side of the Inlet, with perceptible velocities down to a depth of 65-100 feet, while ebbing is mostly confined to the surface layer along the western shore.

A large eddy (or circular, whirlpool-like current) occurs in the broad central region of the Inlet, near the cannery. From the cannery, currents on the western shore generally move in a southward direction, and currents on the eastern shore tend to be directed northward during all phases of the tide.

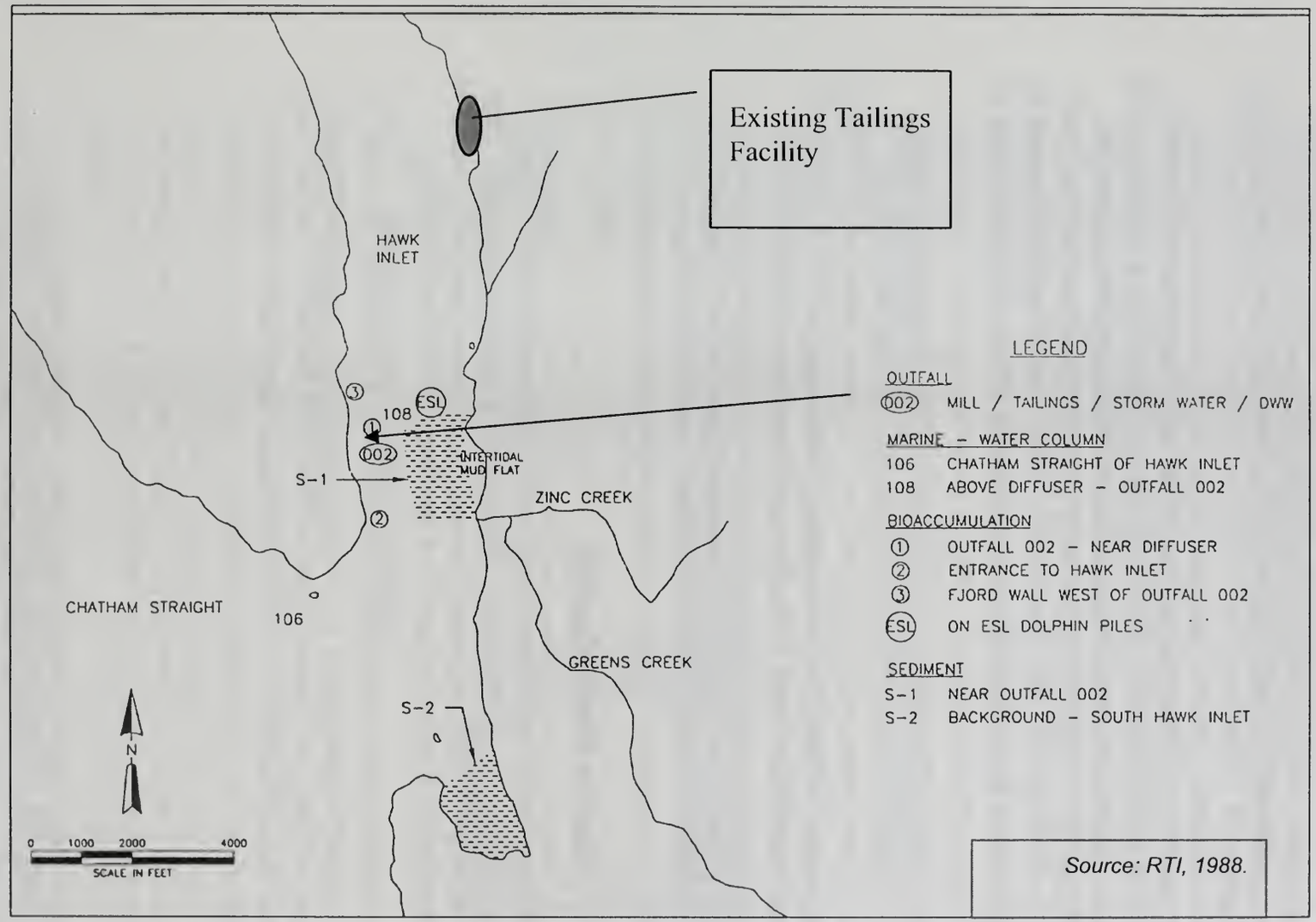
3.6.4 Flushing

Flushing describes the rate and extent to which a body of water is replenished by tidal or other currents. Flushing rates are also indicative of the length of time that mining effluent may remain in a water body and become incorporated into the physical and biological ecosystem.

In 1981, SEA Associates, Inc., conducted flushing studies in Hawk Inlet by observing dispersion of colored dyes in seawater. Based on these studies, it was estimated that over each tidal cycle, an average of 50 million cubic meters (or 13 billion gallons) was flushed from the Inlet. At that rate, it is estimated that the Inlet will completely flush at least once every five tidal cycles. The input of effluent from the existing mining operations over this flushing period represents approximately 0.009 percent of the total flushing volume (Andrews, 1996).

Another study, conducted in 1984, used dyes to examine the length of residence and the rates of flushing of conservative substances (chemicals that do not readily dissolve in seawater) released into Hawk Inlet. The results of that study also indicated that, overall, Hawk Inlet has a relatively good exchange of tidal water (RTI, 1998).

Figure 3-8 Greens Creek Mine Marine Sampling Stations and Outfall Locations



Source: RTI, 1988.

3.6.5 Seasonal and Freshwater Effects on Seawater Mixing

While the rate of exchange between the waters of Hawk Inlet and Chatham Strait fluctuates with the amount of precipitation and with the lunar cycle, which markedly affects tidal currents, mixing within the Inlet is influenced by local features.

The topography and freshwater input into Hawk Inlet create a water mixing environment much like those found in estuaries. Where tidal waters meet fresh waters in estuaries, the more buoyant, fresher waters tend to move seaward along the surface, while the heavier, salty (or *saline*) tidal waters move inland below the fresher water. This slow mass exchange pattern is superimposed on the much more vigorous and rapid circulation that occurs with each change of the tide.

Although wind and geography influence mixing, the net circulation rate is affected substantially only by tidal variations and by fluctuations in the amount of fresh water coming into the Inlet.[4] Six minor tributaries enter on the western shore of Hawk Inlet. The largest tributary is Greens Creek, which, in combination with Cannery Creek, other smaller streams, runoff and direct precipitation falling on the waters of Hawk Inlet, contribute to the gross freshwater entering the system. The amount of fresh water flowing into the Inlet from these tributaries peaks in September and October (because of precipitation) and again in May and June (because of melting snow).

3.6.6 Marine Water Quality

Marine water quality parameters are monitored on a regular basis in Hawk Inlet. Salinity and temperature measurements have been made routinely since 1981. Salinity increases with depth throughout the estuary and stratification is dependent on the location, volume and frequency of fresh water inflows.

Salinity in the vicinity of the outfall pipe exhibited a wide range of levels: 22 to 32 parts per thousand (ppt). In the latter half of 2002, water temperatures averaged 44.6 degrees Fahrenheit at five feet below the surface. Salinity and temperature vary slightly over a tidal cycles, but vary widely in intertidal habitats.

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4. Just over half of the fresh water entering the Inlet comes from Greens Creek, Cannery Creek, and other drainages; most of the rest comes from run-off from the surrounding land; only about five percent comes from direct precipitation over the Inlet surface. International Environmental Consultants, Inc., 1978, 1979, and 1980.

Total suspended solids (TSS) averaged 56.8 mg/kg. With an average pH of 7.99, the water was slightly alkaline. Turbidity averaged 0.556 Nephelometric Turbidity Units; trace elements were also measured (RTI, 1998).

Marine receiving waters (into which outfalls flow) have also been monitored for heavy metals quarterly since 1982. Analytes, method detection limits, sampling stations and frequency of sampling have been determined under the NPDES permit process and results are routinely compared to water quality for aquatic life and human health standards. This limited ongoing marine water quality monitoring shows that lead concentrations in Hawk Inlet and outside the sill vary, with location, from below detection limits to near acute levels (OIO,1984-2002 & RTI, 1998). Select metal data from prior to mine operations and just after mine operations began are found in the table below. Additional data on marine water quality, effluent constituents, and results of toxicity testing can be found in NPDES permit documentation and the (OIO, 1984-2002 & RTI, 1998) Risk Assessment report for NPDES permit #AK-004320-6.

Table 3-2 Average receiving water monitoring data for control site (106 – Chatham Strait) and outfall 002 diffuser site (108) *(See Figure 3-8)*

Period	Parameter	Station 106 ug/L	Station 108 ug/L
Pre-Operational (1982-1986)	Lead	0.148	0.059
	Copper	0.783	0.694
	Zinc	1.669	2.231
Operational (1989)	Lead	0.06	1.2
	Copper	0.82	1.05
	Zinc	0.44	0.44

(OIO1984-2002 & RTI 1998)

3.7 Geology and Geochemistry

3.7.1 Regional Geology

The rocks and sediments found in the project area were formed over an extended period of geologic time through volcanic action. The bedrock consists of structurally complex Paleozoic age rocks that have been metamorphosed, folded and faulted. The primary rock types include quartz schist, carbon rich argillite, and phyllite, each of which contains traces of pyrite.

The topography, landforms, and shallow sediments in the project area were formed in the more recent geologic past through glacial and marine processes. During the last period of glaciation, an extensive ice sheet flowed outward from higher elevations east of Admiralty Island and buried all but the highest

peaks on the Island. Based on radiocarbon dating of peat deposits elsewhere in Southeast Alaska, the glaciers are estimated to have retreated about 13,000 years ago.

The vast glacial ice layer that covered Southeast Alaska depressed the land surface by hundreds of feet. After the ice melted, the land gradually recovered in a process known as *isostatic rebound.* Rebound of more than 600 feet has been recorded in Southeastern Alaska. As the ice and water retreated, it carved marine beach terraces around the edges of Admiralty Island. The proposed tailings expansion area is situated on the remnant of one such beach terrace.

After landforms emerged above sea level, native vegetation became established and because of the cool, wet climate found on Admiralty Island, peat deposits formed, especially on the flatter slopes of the marine terrace features.

3.7.2 Local Bedrock Geology and Geochemistry

The action of glacial ice and water on and around Admiralty Island created the sequence of sediments that are found beneath the proposed tailings expansion area. The foundation for recent sediments is a convoluted bedrock system comprised of argillites and phyllites that have been shaped by glacial ice and erosion. Although the rock units around the tailings facility have not been extensively tested, many samples of argillite and phyllite have been collected from the mine area and production rock piles. The rock units near the ore zones may be more strongly mineralized than those in the tailings area.

Samples of argillite from the mine and production rock piles contain small amounts of minerals such as pyrite that form sulfuric acid when exposed to oxygen (the process of sulfide oxidation). Argillite also contains a high volume of carbonate minerals such as dolomite and lesser amounts of calcite—minerals that partially dissolve and, through the process of sulfate reduction, neutralize acidity from sulfide oxidation. As a result of these processes, water in contact with argillite rocks will typically have a neutral pH and will contain soluble calcium, magnesium, bicarbonate, and sulfate ions. Because argillite has proportionately more carbonate minerals than pyrite, the rock unit should remain neutral in pH. Argillite rocks are also known to be somewhat enriched in zinc (though at lesser concentrations than in ore) so that water contacting these rock may contain elevated zinc levels.

Like argillite, phyllite contains both pyrite and dolomite. Unlike argillite, however, phyllite has proportionately more pyrite than dolomite. As a result, carbonate minerals, such as dolomite, may be depleted before the process of sulfide oxidation is complete. Geochemical tests on samples of phyllite from the mine indicate that these rocks (unlike the argillite) may become acidic

after several years of weathering. The rate of acid generation of both rock units is described in more detail in Shepherd Miller (2000).

3.7.3 Local Unconsolidated Sediments

Eroded bedrock protrudes from the mantle of glacial and marine sediments in places, leading to a complex series of sediments that vary in thickness. Compacted till (sediments left by glacial activity) fill the deeper bedrock basins (Ager, 2001). Around the site of the proposed tailings area, the compacted till is overlain in places by deposits of deeper marine sediments that are comprised of organically enriched silts and clays. As water retreated, shallower marine sediments were deposited over the deeper marine sediments. Locally, the deeper sediments were removed as the more erosive intertidal and shallow marine system evolved. The uppermost shallow marine sediments are often coarser-grained than the deeper marine sediments and contain abundant shell fragments. Thin lenses of glacial till or colluvial sediments (soils) are sometimes found overlying the shallow marine layer. Finally, on flatter slopes, a layer of peat has developed that varies from a few feet to tens of feet in thickness.

3.7.4 Drainage Basin Physiography and Topography

The existing tailings facility is located at the headwaters of the Tributary Creek drainage basin and the Hawk Inlet drainage area. (See Figure 3-9). The northern-most portion of the existing tailings facility is adjacent to the Cannery Creek drainage basin. A small upland area located to the east of the tailings facility drains toward the tailings. Surface runoff from the existing pile is collected and diverted to the water treatment plant. Treated effluent flows from the treatment plant through a pipeline located on the west side of the tailings facility and discharges directly into Hawk Inlet through a submerged diffuser. This discharge is regulated by a National Pollutant Discharge Elimination System (NPDES) Permit.

The Tributary Creek basin is approximately 482 acres, 29 acres of which are covered by the existing tailings pile. The pile is buffered from both surface and ground water infusion: a series of diversion ditches transport surface water away from the tailings facility, while slurry walls and French Drains divert groundwater flow.

The Tributary Creek basin gently slopes to the south towards Zinc Creek, and primarily consists of muskeg vegetation interspersed with stands of timber. Prior to construction of the tailings facility, the headwaters of Tributary Creek were the slopes east of the tailings facility and the muskeg area within the footprint of the tailings facility. Since construction of the tailings facility, the headwaters of Tributary Creek are small seeps and numerous small channels

flowing through muskeg to the south of the tailings. Additionally, surface flow and run-off from the east of the tailings facility are captured in a lined perimeter interceptor ditch and routed south to the Tributary Creek muskeg area and north to Cannery Creek. The seeps and channels lying to the south of the tailings facility are fed from the shallow groundwater regime in the peat and sand substrate. These perennial flows eventually combine approximately 2,000 feet downstream of the existing tailings facility to form a distinct stream channel. Tributary Creek then flows into Zinc Creek, which flows into Hawk Inlet near the mouth of Greens Creek.

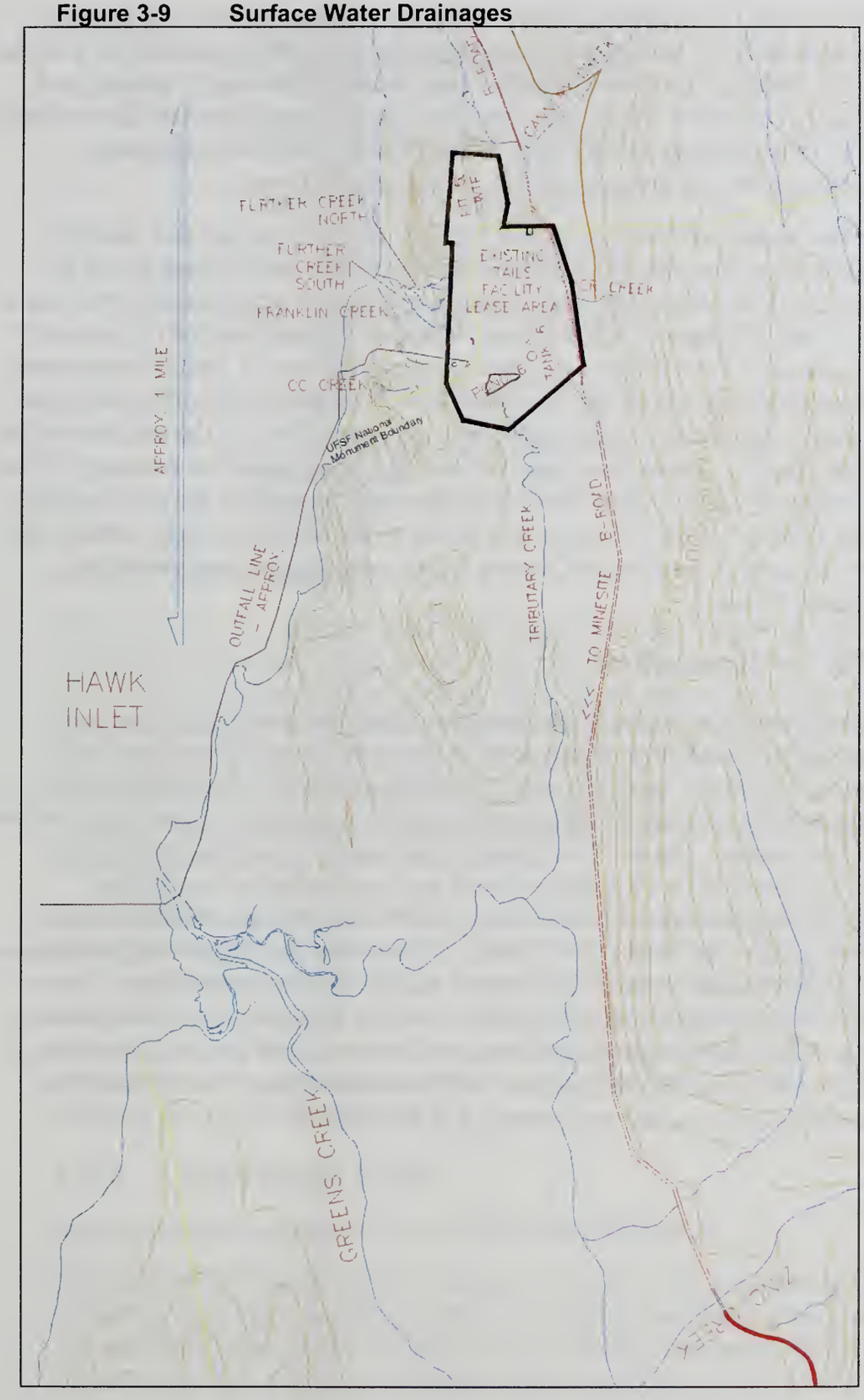
The Hawk Inlet drainage area lies immediately to the west of the existing tailings facility and Tributary Creek. This catchment has an area of approximately 76 acres, of which approximately 5 acres are covered by hydraulically contained areas of the existing tailings facility. This drainage has a northern aspect, and consists of terraces intermixed by steep slopes. The vegetation is primarily muskeg and timber. The muskeg-covered terraces contain numerous seeps that are surface expressions of precipitation-induced recharge to the peat and sand substrate.

One particular seep of interest is called Further Seep, an intermittent seep with a flow approximating 1 gpm. Several small streams form within the drainage area as a result of the seeps and surface water runoff. These streams are known locally as CC Creek, Proffett/Franklins Creek, and Further Creek (South Fork, North Fork). CC Creek and Further Creek discharge directly to Hawk Inlet. Proffett Creek can be traced a few hundred feet on the surface before it sinks into the underlying strata.

Another surface stream appears about 100 feet down gradient, and appears (based on similar water chemistry) to be the same flow. This lower stream is known locally as Franklins Creek, which discharges directly to Hawk Inlet. Another surface water feature is a man-induced spring called Duck Blind Drain. This surface water feature has resulted from construction of the pipeline that discharges treated water into Hawk Inlet. Water that naturally collects within the pipeline trench alignment is allowed to discharge to the surface through a pipe at the location of a pipeline valve vault. This vault contains a flow meter that monitors flow through the pipeline, and the discharge pipe is used to keep the vault from becoming flooded. The flow from this source is less than 0.5 gpm.

The Cannery Creek basin lies to the north and east of the tailings facility. It is a perennial stream that drains to the north in its upper reaches, then curves south and west, crosses under the B road and flows adjacent to the northern edge (Pit 5) of the tailings facility. From the B road bridge, it flows to the northwest of the tailings facility and empties in Hawk Inlet near the Cannery buildings.

Figure 3-9 Surface Water Drainages



The Cannery Creek drainage basin is approximately 625 acres, of which approximately six acres are covered by the hydraulically contained area of the tailings facility. The drainage basin is for the most part steeply sloping and primarily covered with timber. A muskeg bog is located between the northeast corner of the tailings facility and Cannery Creek. Shallow groundwater emerging from this area makes its way to Cannery Creek.

Another source of flow to Cannery Creek is diverted surface and shallow groundwater flow emanating from a small drainage area located above the east side of the tailings facility. Before development of the facility, this was a part of the Tributary Creek drainage. This area is comprised of 107 acres of steep, densely wooded terrain with a western exposure. A single watercourse, known locally as GR Creek, and sheet flow from surface runoff move down gradient where they are intercepted by a diversion ditch on the east side of the tailings facility. These flows are captured in a lined perimeter interceptor ditch and a French drain system above the slurry wall located on the east boundary of the facility. Of the 107 acres that drains to the diversion ditch, surface flow from 65 acres is diverted to Cannery Creek, and 42 acres is diverted to Tributary Creek.

3.7.5 Streamflow

Limited data exists regarding streamflows. Surface water flows fluctuate seasonally in the four drainage areas in response to rainfall and snowmelt events. High flows generally occur in spring as a result of snowmelt, and again in fall as a result of high rainfall periods. Low flows occur in mid-winter and late summer. Stream flow data for the creeks surrounding the tailings facility are either non-existent; or have not been collected in sufficient amounts to generate statistical indices based on actual flow measurements. However, flow estimates for Tributary Creek were developed using regression techniques as part of the 1981 baseline studies for the Greens Creek Project (Ott, 1981). Estimated mean monthly flows for Tributary Creek are shown in Table 3-3. Even though these estimates were developed prior to construction of the existing tailings facility, they still provide a general indication of the magnitude of flows that are generated in this stream.

Table 3-3 Mean Monthly Flows for Tributary Creek[1]

Month	Flow (cfs)
Jan	1.2
Feb	1.6
Mar	1.9
Apr	3.5
May	4.2
Jun	2.4
Jul	1.0
Aug	1.5
Sep	3.8
Oct	4.5
Nov	3.0
Dec	1.4
Mean Annual	**2.5**

[1] *From Ott, 1981*

3.7.6 Groundwater

There is no known regional aquifer system in the area, but groundwater resources occur under a wide range of conditions. The many small drainages and irregular topography and geology make for numerous small-scale aquifers and groundwater flow systems. Groundwater can be found in manmade fill, peat, sand and gravel, till, and fractured bedrock aquifers. Confining materials include compressed peat beneath the existing tailings and the underlying silt and clay. Where bedrock is exposed or near the land surface, the sedimentary aquifers and confining materials are absent.

The remaining sections within this chapter describe groundwater resources at the site of the proposed expansion. Various sections discuss the general hydrogeologic setting, provide an overview of the geologic materials (sometimes referred to as *units*) present in the area, discuss those materials in terms of their potential as aquifers or confining units, and describe groundwater flow systems and variations in those flow systems caused by seasonal and manmade features.

3.7.7 Hydrologic Units

Hydrologic units present at the site include the following.

Man-Made Fill. Manmade fill is present in the area and is comprised mainly of tailings from mine workings. Fill also includes road and drainage structures and reworked materials in excavated areas. Tailing material, predominantly silt-sized crushed ore residues that are stacked and compacted, have typical residual volumetric moisture content of +/- 28 percent.

Peat. Peat is dense organic matter, often containing root masses and stumps. It was found widely throughout the site prior to development, except on some of the steeper sloping areas. Peat has been excavated in some areas prior to deposition of the tailings. The peat varies in thickness, with a maximum thickness of approximately 20 feet.

Sand. Sand occurs as a relatively thin layer across much of the site directly beneath the peat. The sand is generally coarse and gravelly, with a moderate amount of silt and traces of marine shell fragments. The sand is interpreted to have resulted from beach or alluvial deposits during periods of higher relative sea level. The sand in places is over 20 feet thick, but in most areas of the site, it is about 2 to 10 feet thick.

Silt with Clay and Sand. Directly beneath the sand layer that covers most of the site is a relatively continuous layer of silt with clay and sand. This layer reaches 50 feet in thickness in places, and it is sometimes inter-tongued with the underlying till deposits. Analyses of this layer indicate that it is made up of approximately 40 percent silt, 30 percent clay, and 30 percent sand. The layer is referred to as the "silt layer" in this document, with the understanding that clay and sand are significant components.

Till. Till at the site is an irregular mixture of sand, silt and clay, gravel, and cobbles, in decreasing order of abundance. Isolated pockets of stratified sand and gravel from glacial activity are also found. Till is present throughout much of the area except where shallow bedrock is present. The thickness of till averages about 15 feet, but it is up to 60 feet in places. The till lies beneath the silt layer and directly above the bedrock. The till also contains layers of silt or clay that suggest quiet marine water deposition or wetland deposition intermittent with till deposition.

Bedrock. Bedrock in the area consists of hard, banded schist, phyllite, and argillite. These rocks are metamorphosed from volcanic and marine sedimentary rocks. The bedrock surface is highly irregular—in some places it stands out with minimal soil cover, in others, basins are filled with layers of till, silt, sand, peat, and manmade fill. The bedrock in the project area is not highly fractured, although there may be increased fracturing near the surface in areas where blasting occurs.

3.7.8 Aquifers and Confining Units

Groundwater is found in several aquifers and, to a lesser degree, in confining units beneath the existing tailings pile. This section describes the aquifers and the materials that act as confining units in the area of the proposed project. Figure 3-10 shows a conceptual model of where groundwater occurs and how it moves in the area.

Peat/Sand Aquifer. The peat and sand units are physically adjacent and function as a single aquifer except where buried by fill. Beneath portions of the tailings pile where the peat has not been removed, the peat is compressed and functions like a confining unit.

Silt Confining Unit. The peat/sand aquifer is underlain by a silt layer that functions in places as a confining unit between the peat/sand aquifer and the underlying till aquifer. Figure 3-11 shows the extent of the silty clay layer at the site, along with the distribution of peat and till deposits. In places these units are all absent; however, in other areas they are all present and provide multiple layers of low permeability material underlying the site.

Till Aquifer. Groundwater in till is found mainly in isolated small sand and gravel lenses within the till. The majority of the till is of relatively low permeability and is intermediate in permeability between sandy units and silt/clay units at the site. On a local scale, the siltier portions of the till serve as a confining unit for sand and gravel units within the till.

Bedrock Aquifer. The entire area is underlain by bedrock that contains groundwater in fractures. In areas where bedrock is near the surface, groundwater is considered to be unconfined; in areas where the bedrock is covered by other materials, groundwater is considered to be confined.

3.7.9 Groundwater Flow Systems

Groundwater flow systems at the project area are complex. Flow systems are driven by local precipitation and snowmelt and the local terrain. With average annual precipitation at the site of approximately 53 inches, a surplus of water is frequently available for groundwater recharge. Much of the annual precipitation runs off from saturated or low-permeability surfaces in the area; however, a recharge rate of approximately 6.5 inches/yr has been estimated for groundwater recharge into the tailings (EDE, 2002A).

Detailed flowpaths are strongly influenced by local geological features, hydraulic control structures associated with the existing tailings facility, and surface water drainages. The site generally straddles a three-way divide, with groundwater flow components draining towards Cannery Creek to the north, Tributary Creek to the south, and Hawk Inlet to the west.

Groundwater Flow Patterns. Figure 3-12 shows generalized groundwater flow patterns in the area.

Flow within the till and bedrock travels under the tailings pile in a predominantly westward direction towards Hawk Inlet. Groundwater in the shallow peat/sand aquifer that is uphill from the tailings pile flows around the pile because of the system of diversionary barriers and drains. Flow within the

pile and in the sand aquifer beneath it is predominantly southward towards the system of slurry wall barriers, drains and sumps around the perimeter of the facility. Water that is collected is withdrawn, treated, and discharged to Hawk Inlet.

Groundwater also discharges to Cannery Creek and Tributary Creek, as well as to small intermittent drainages on the west side of the tailings pile. Cannery and Tributary Creeks are perennial streams that are observed to flow even during dry spells. A number of rivulets appear near the tailings pile and feed into these streams.

Groundwater in the bedrock knob on the northwest corner of the facility flows away from the high point of the knob in all directions. Groundwater flows in an easterly direction from the bedrock knob towards Pit 5 and Cannery Creek and can be seen in Figure 3-12.

3.8 Hydrology

3.8.1 Groundwater Quality

Groundwater quality is described based upon water quality samples from monitoring wells and surface sampling sites located both uphill (upgradient) and downhill (downgradient) from the tailings facility (Figure 3-13). Extensive analyses of data from these samples have occurred as part of the baseline studies produced for this EIS (EDE, 2002a; 2002b), the annual Fresh Water Monitoring Program (FWMP) reports submitted to the Forest Service by KGCMC, and a third-party technical review of the FWMP (Shepherd Miller, Inc., 2000). This section presents an overview of that information.

Several monitoring wells are used as part of the FWMP conducted by KGCMC as described in the GPO (KGCMC, 2001a). Water quality data from these wells date back to 1988, prior to construction of the tailings pile. These wells are completed in the shallow peat and the deeper bedrock zones, and located to the south and west (down-gradient) of the tailings facility. These wells are monitored to evaluate the impacts of the tailings facility, if any, on local groundwater quality. A summary of groundwater quality data from FWMP monitoring wells located downgradient of the existing tailings pile is shown in Table 3-4. These data represent water quality sampling reported annually to the Forest Service as required by the FWMP.

In general, groundwater quality in the downgradient FWMP wells is characterized as having near-neutral pH in the deeper bedrock till/sand wells and lower pH in the wells completed in the shallow peat (typical of muskeg waters). Water quality data from these wells are relatively consistent between monitoring well pairs (shallow and deep) with the exception of pH, and do not

show groundwater quality impairment as a result of mining activities near the tailings facility.

Several regulatory agencies and KGCMC participated in a third-party review of water quality data and waste rock/tailings management in 1999 – 2000. One aspect of this review was to evaluate the FWMP, including monitoring practices, laboratory protocols, sampling locations, and data interpretation. The review resulted in a report that contained several recommendations and conclusions, including a statement to the effect that no trends in increasing metal and sulfate levels or acidity were evident (Shepherd Miller Inc., 2000).

Table 3-4 Groundwater Quality – FWMP Wells

Analyte	MW-2S FWMP #27 Peat (range, average)	MW-2D FWMP #28 Deep Till (range, average)	MW-3S FWMP #29 Peat (range, average)	MW-3D FWMP #30 Bedrock (range, average)
Total Alkalinity, mg/l	22-206, 85	89-410, 117	0.1-120, 72	187-394, 282
Hardness, mg/l	11-150, 69	54.8-78.8, 69	25.7-132, 65	13-72, 31
Conductivity, umhos/cm	10-400, 201	150-560, 220	19-250, 165	330-688, 494
pH, lab, s.u.	5.4-8.5, 6.3	6.4-9.9, 8.2	4.8-7.8, 6.0	7.78-9.35, 8.3
Arsenic, dissolved, µg/l	ND-13, 0.48	ND-141, 73.00	ND-36, 16.22	ND-49, 29.48
Barium, dissolved, µg/l	ND-1000, 37.0	ND-90, 3.5	ND-600, 33.2	ND-720, 26.1
Cadmium, dissolved, µg/l	ND-58, 0.68	ND-3.0, 0.06	ND-3.0, 0.03	ND-3.0, 0.03
Chromium, dissolved, µg/l	ND-5.28, 0.054	ND-0.52, 0.025	ND-3.4, 0.192	ND-4.14, 0.073
Copper, dissolved, µg/l	ND-30, 2.65	ND-10, 0.51	ND-23, 1.69	ND-20, 1.69
Lead, dissolved, µg/l	ND-2.34, 0.102	ND-0.0609, 0.00006	ND-21.0, 0.42	ND-30, 0.67
Mercury, dissolved, µg/l	ND-0.00448, 0.00021	ND-0.00137, 0.00005	ND-0.00248, 0.00014	ND-0.00153, 0.00004
Nickel, dissolved, µg/l	ND-50, 3.21	ND-40, 1.56	ND-70, 3.45	ND-20, 1.44
Selenium, dissolved, µg/l	ND-0.219, 0.0047	ND-0.287, 0.0027	ND-0.2380, 0.0066	ND-0.28, 0.0028
Silver, dissolved, µg/l	ND-0.172, 0.0024	ND-0.0536, 0.0012	ND-0.162, 0.0019	ND-2.0, 0.020
Sulfate, mg/l	ND-12, 1.84	9-150, 13.17	ND-10.7, 1.55	ND-13.4, 1.42
Zinc, dissolved, µg/l	ND-220, 24.85	ND-54, 3.29	ND-230, 24.14	ND-210, 7.99

ND = non-detect. Detection limits have varied over the years. Current and past detection limits are listed in (KGCMC, 2001a). Data collected 1988-2002; *Data compiled from KGCMC water quality database (KGCMC, 2003).*

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Figure 3-10 Conceptual Model of Groundwater Occurrence and Flow in the Area of the Existing Tailings Facility (EDE, 2002a).

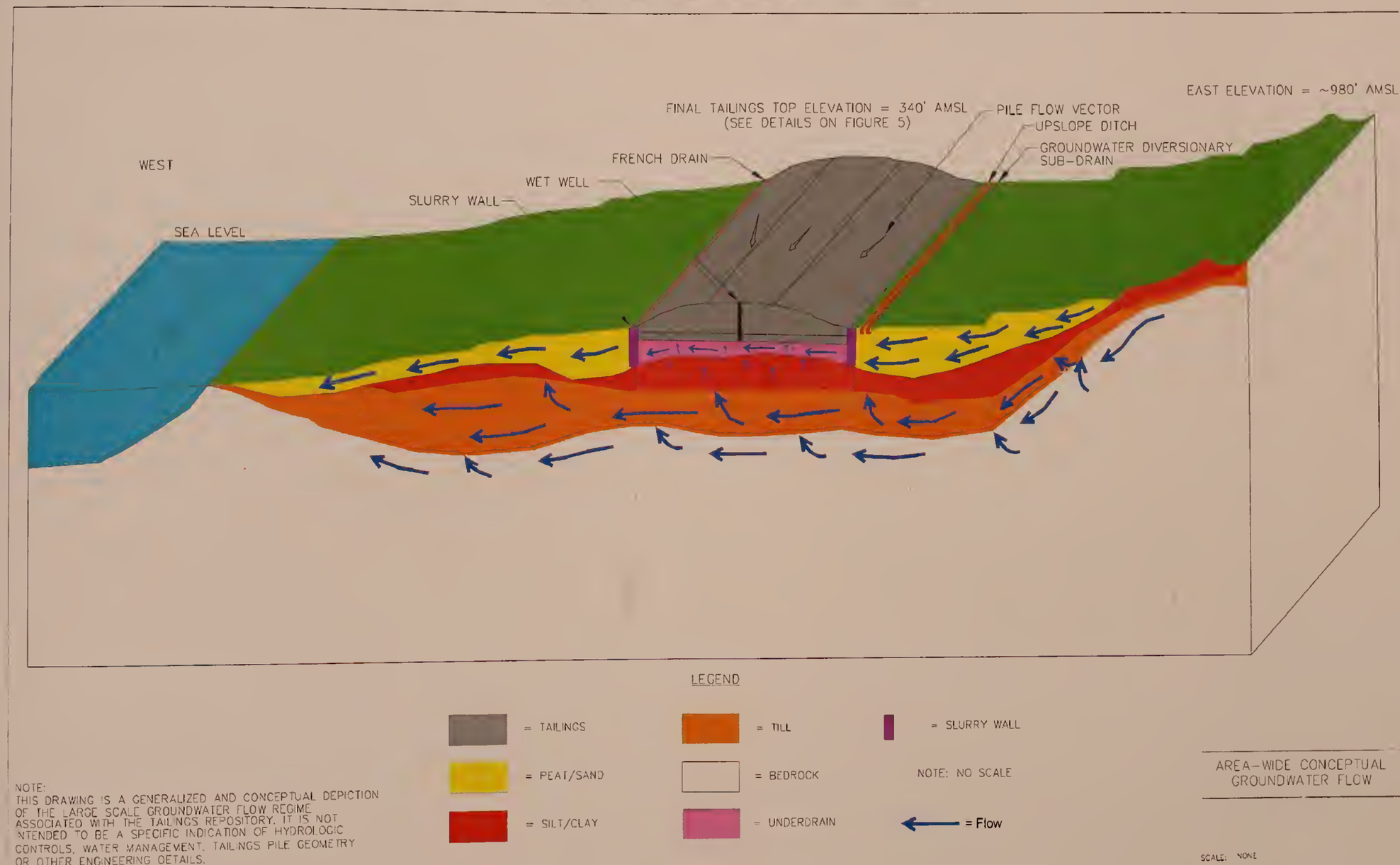


Figure 3-11 Extent of the Silty Clay Layer at the Site, along with the Distribution of Peat and Till Deposits

Figure 3-12 Generalized Ground Water Flow Pattern for Alternative C (EDE 2002b)

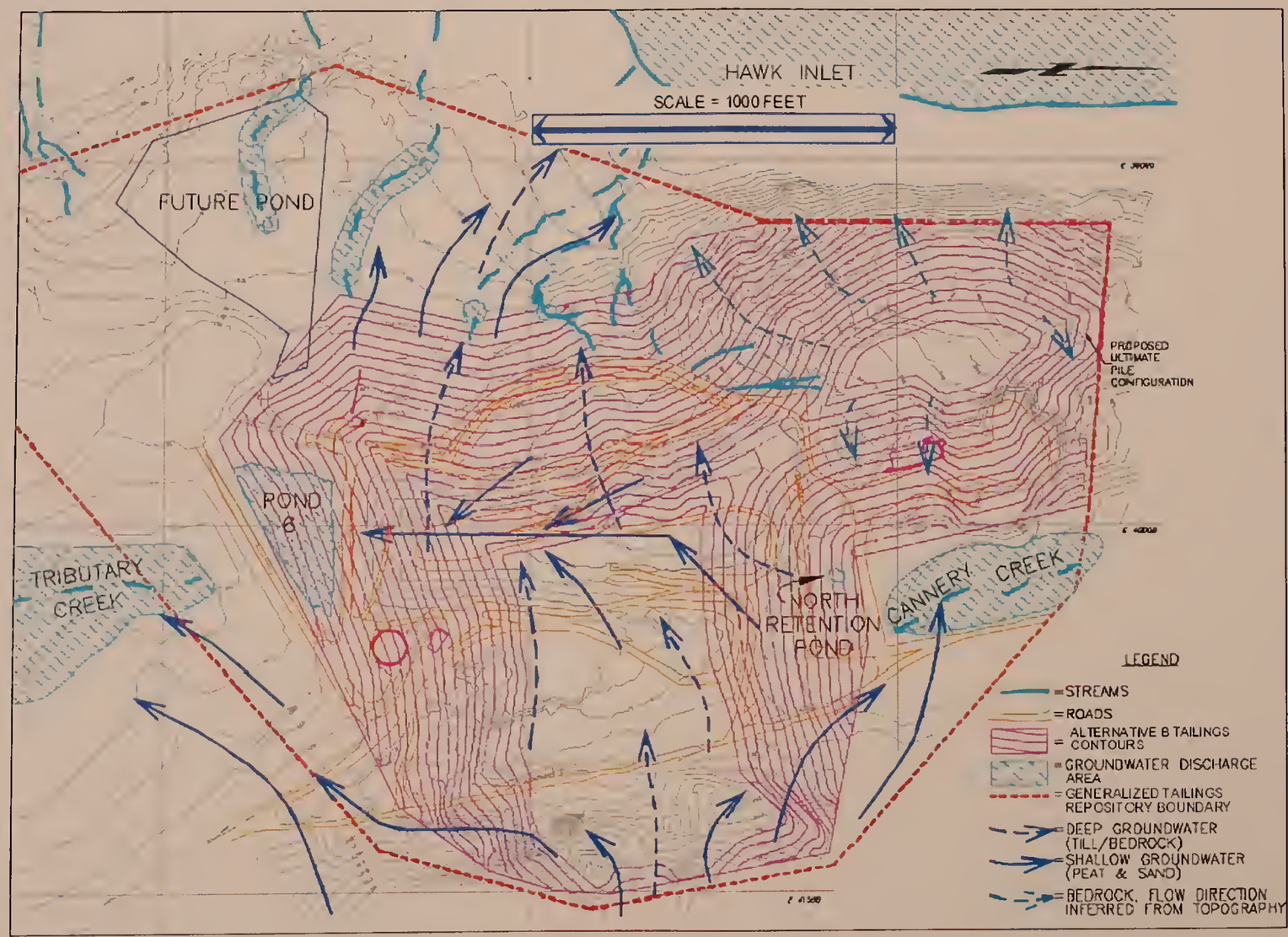
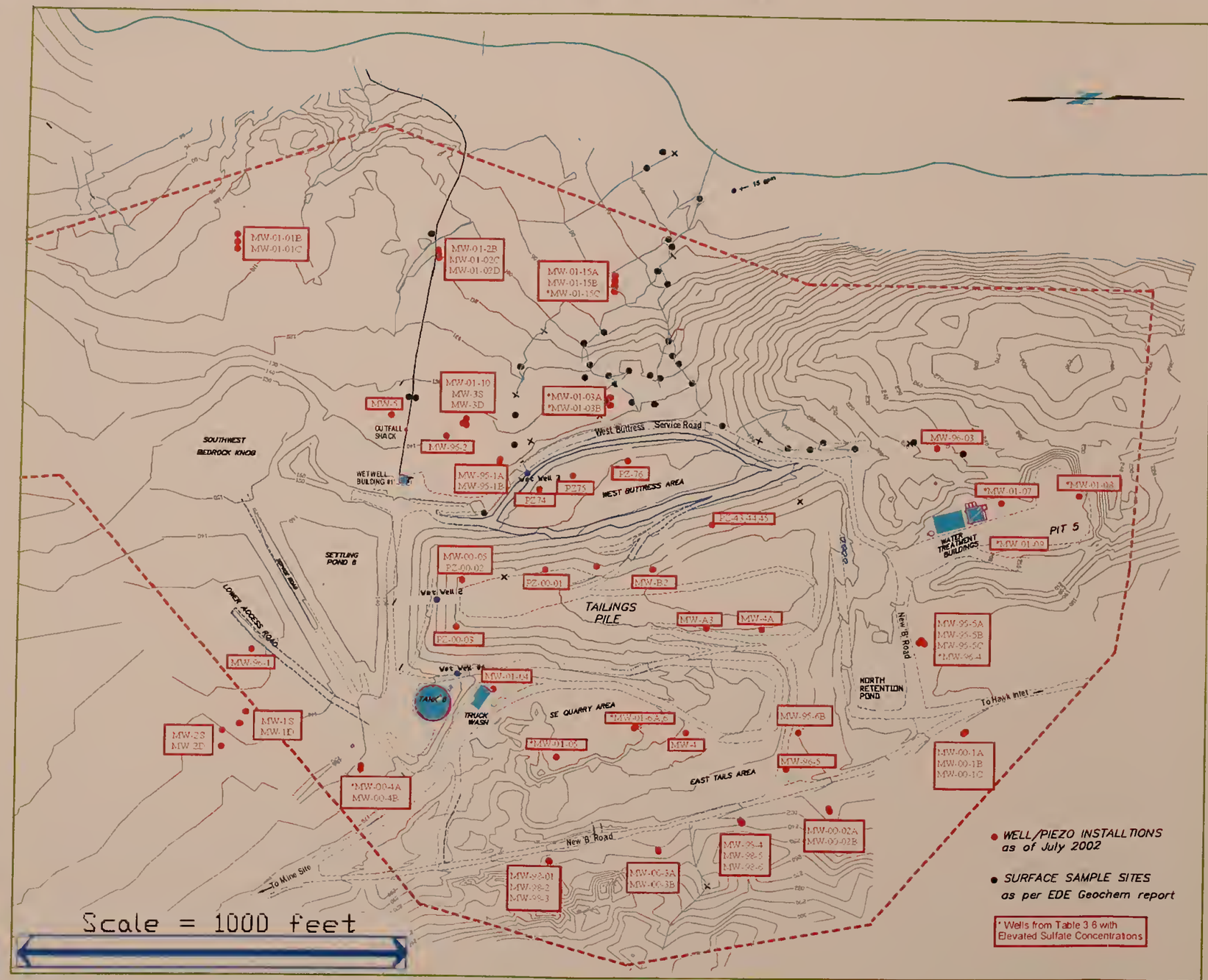


Figure 3-13 Monitoring Wells (MW) and Sampling Sites Located Upgradient and Downgradient from the Tailings Facility (EDE, 2002a)



Two new FWMP monitoring wells were installed by KGCMC in 2000 to replace an older well (MW-4, FWMP #31) that became obsolete when this expansion project began in 2000. These new wells were completed uphill from the tailings pile. Several other monitoring wells are also located uphill from the tailings pile, but are not included in the FWMP (Figure 3-13) These additional wells were constructed between 1998-2001, and are completed in the peat, sand, and till zones. All of these wells are located upgradient from any mining-related activity. Water quality data from these wells are summarized in Table 3-5. Due to the limited number of times these wells have been sampled, these data are combined according to water quality parameters. The data show near neutral pH for those wells in the sand and till, and a lower pH for those wells completed in the peat due to organic acids from decomposing vegetation.

Table 3-5 Groundwater Quality Summary – Upgradient Wells

MW-98-2, MW-98-3, MW-98-5, MW-00-3A, MW-00-3B, MW-00-2A, MW-00-1B, MW-00-1A (FWMP #59), MW-00-1C (FWMP #58)

Analyte	Peat, sand, till (range, average)
Total Alkalinity, mg/l	30-120, 78
Hardness, mg/l	27.5-106, 62.1
Conductivity, umhos/cm	45-241, 167
pH, s.u.	5.2-7.6, 6.3
Arsenic, dissolved, µg/l	0.5-12.6, 3.2
Barium, dissolved, µg/l	7.1-253, 50.1
Cadmium, dissolved, µg/l	ND
Chromium, dissolved, µg/l	0.46-9.7, 1.6
Copper, dissolved, µg/l	0.5-10.2, 1.7
Lead, dissolved, µg/l	0.2-6.6, 1.6
Mercury, dissolved, µg/l	ND
Nickel, dissolved, µg/l	0.5-8.4, 2.2
Selenium, dissolved, µg/l	ND-7.1, 1.2
Silver, dissolved, µg/l	ND-1.0, 0.3
Sulfate, mg/l	2.7-78.6, 11.5
Zinc, dissolved, µg/l	ND-123.0, 13.2

ND = non detect. From (EDE, 2002b)

The data also show low sulfate concentrations, and low values of dissolved metals.

Analyses of water quality samples from other non-FWMP wells located downgradient (north, south, and west) of the tailings pile indicate some anomalous (i.e., high relative to background) sulfate concentrations. Higher concentrations of metals and lower pH values were not observed in these wells. The wells include MW-01-07, MW-01-08, MW-01-09, MW-01-03A and MW-96-4 on the north side; MW-00-04A, MW-01-06A, MW-01-06B, and MW-01-05 on the south side; and MW-01-15C, MW-01-03B, and MW-01-03A on the west side (Figure 3-13). Water quality data from these wells are shown Table 3-6. An extensive evaluation was conducted to determine the source(s) of the higher sulfate values (EDE, 2002a).

Table 3-6 Water Quality from Wells Showing Elevated Sulfate Concentrations

		MW-01-15C 6/7/01	MW-01-15C 9/6/01	MW-01-3B 6/14/01	MW-01-3B 9/4/01	MW-01-05 4/4/01	MW-96-4 5/24/01
Aluminum	ug/l, diss	193	106	135	<100	247	298
Boron	ug/l, diss	<100	<100	208	183	<100	122
Barium	ug/l, diss	48	41	225	191	138	49
Calcium	mg/l, diss	55	59.1	55.7	58.8	35.6	104
Iron	ug/l, diss	140	105	<100	227	291	1660
Magnesium	mg/l, diss	11.5	10.9	31.1	33.3	71.2	28.8
Sodium	mg/l, diss	48.8	51.1	99.9	83.4	5.27	26.8
Arsenic	ug/l, diss	30.6	2.62	2.78	1.56	3.31	51.8
Antimony	ug/l, diss	3.46	<1.0	4.19	2.76	4.53	<1.0
Cadmium	ug/l, diss	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1.0
Chromium	ug/l, diss	1.15	1.16	<1.0	<1.0	0.78	1.29
Copper	ug/l, diss	3.38	<2.0	2.24	<2.0	1.26	7.62
Lead	ug/l, diss	0.3	<1.0	<1.0	<1.0	0.26	<0.2
Manganese	ug/l, diss	725	455	551	1100	162	871
Molybdenum	ug/l, diss	15.4	13.0	17.4	14.6	7.0	40.8
Mercury	ug/l, diss	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	ug/l, diss	7.35	6.96	<2.0	<2.0	0.69	1.76
Selenium	ug/l, diss	2.39	<1.0	5.88	3.05	<1.0	1.6
Silver	ug/l, diss	0.2	<1.0	<1.0	<1.0	0.4	<1.0
Zinc	ug/l, diss	4.0	<5.0	8.35	5.85	<1.0	<5.0
Potassium	mg/l, diss	9.66	8.35	12.9	10.7	1.67	5.37
Lab pH	s.u.	7.72	7.24	7.44	7.89	7.82	7.66
Field pH	s.u.	7.12	7.05	7.8	7.68	7.9	7.68
Acidity	mg/l, CaCO3	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Phosphorus	mg/l	0.514	2.3	0.0422	0.0377	0.0263	0.0645
Orthophosphat	mg/l	1.49	13	0.0149	0.0107	0.0149	0.0224
DOC	mg/l	10.2	6.96	4.18	<4.0	2.3	3.51
Bicab Alkalinity	mg/l CaCO3	211	219	122	148	80.4	164
Total Alkalinity	mg/l CaCO3	211	219	122	148	80.4	164
Silica	mg/l	21.1	21.9	9.4	8.33	11	56.5
Chloride	mg/l	4.91	5.16	173	143	2.95	5.47
Fluoride	mg/l	0.237	0.292	0.409	0.352	<0.1	0.257
Nitrate-N	mg/l as N	<0.1	<0.1	0.193	0.35	<0.1	<0.1
Nitrite-N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/l	84.2	96.2	170	201	29.3	247
Sulfide	mg/l	0.0805					<0.05
Lab Sp. Cond.	uS/cm	565	648	1090	1020	226	790
Field Sp. Cond.	uS/cm	593	880	880	1044	234	784
TDS	mg/l	440	480	680	630	130	550
TSS	mg/l	5	<4.0	<4.0	<4.0	5	7
Hardness	mg/l	47.4	192	267	284	118	378
Field Temp	C	7.9	9.9	8.4	11.1	4.8	9.7

Table 3-6 (continued) Water Quality from Wells Showing Elevated Sulfate Concentrations

		MW-01-06A 4/4/01	MW-01-06B 4/4/01	MW-01-07 5/31/01	MW-01-08 4/4/01	MW-01-09 5/31/01	MW-01-03A 4/9/01
Aluminum	ug/l, diss	111	148	422	233	271	125
Boron	ug/l, diss	<100	<100	146	<100	<100	<100
Barium	ug/l, diss	102	111	47.5	140	83.2	128
Calcium	mg/l, diss	51.8	52.1	326	120	123	48.1
Iron	ug/l, diss	812	<100	123	<100	2390	1460
Magnesium	mg/l, diss	13.2	12.2	38.2	18.0	20.1	16.7
Sodium	mg/l, diss	9.7	23.5	36.6	12.6	7.2	29
Arsenic	ug/l, diss	5.97	3.88	1.02	1.83	1.43	7.22
Antimony	ug/l, diss	0.73	4.3	<1.0	4.24	<1.0	0.92
Cadmium	ug/l, diss	<0.1	0.79	0.21	0.13	0.15	<0.1
Chromium	ug/l, diss	0.56	0.65	2.67	0.51	2.53	0.58
Copper	ug/l, diss	0.68	2.07	1.14	123.0	0.51	1.35
Lead	ug/l, diss	<0.2	0.74	<0.2	0.78	<0.2	0.32
Manganese	ug/l, diss	871	607	2700	141	1890	266
Molybdenum	ug/l, diss	<5.0	5.46	15.1	44	6.07	5.34
Mercury	ug/l, diss	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	ug/l, diss	1.17	3.12	17.1	7.83	10.8	2.61
Selenium	ug/l, diss	<1.0	2.29	2.14	2.52	1.34	2.21
Silver	ug/l, diss	0.41	0.31	<0.1	0.28	<0.1	1.1
Zinc	ug/l, diss	10.2	1.76	9.09	40.5	<5.0	9.57
Potassium	mg/l, diss	5.47	11.5	8.07	9.75	6.8	4.18
Lab pH	s.u.	7.39	7.44	7.24	7.52	7.21	7.47
Field pH	s.u.	7.53	7.6	7.3	7.71	7.14	7.25
Acidity	mg/l, $CaCO_3$	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Phosphorus	mg/l	0.0148	<0.005	0.0198	<0.005	0.0164	0.0249
Orthophosphat	mg/l	0.00242	0.00242	0.00215	0.00296	0.00614	0.00216
DOC	mg/l	4.3	3.58	4.14	4.12	4.86	7.06
Bicab Alkalinity	mg/l $CaCO_3$	147	159	182	189	161	140
Total Alkalinity	mg/l $CaCO_3$	147	159	182	189	161	140
Silica	mg/l	13	12.6	9.74	10.2	6.46	9.95
Chloride	mg/l	4.79	64	33.8	7.35	5.6	2.78
Fluoride	mg/l	<0.1	0.175	0.264	0.233	0.28	0.208
Nitrate-N	mg/l as N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite-N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/l	40	93.2	888	174	210	11.9
Sulfide	mg/l			<0.05		<0.05	
Lab Sp. Cond.	uS/cm	382	704	1750	740	709	289
Field Sp. Cond.	uS/cm	403	484	1641	798	694	452
TDS	mg/l	210	330	1400	490	470	160
TSS	mg/l	4	5	10	<4.0	9	12
Hardness	mg/l	184	180	971	374	390	189
Field Temp	C	5.1	4.3	7.5	5.4	7.9	7

Table 3-6 (continued) Water Quality from Wells Showing Elevated Sulfate Concentrations

		MW-01-3A 9/4/01	MW-00-4A 5/24/01
Aluminum	ug/l, diss	169	100
Boron	ug/l, diss	<100	<100
Barium	ug/l, diss	166	54.6
Calcium	mg/l, diss	35.2	70.4
Iron	ug/l, diss	3460	5790
Magnesium	mg/l, diss	15	9.83
Sodium	mg/l, diss	61.3	20.7
Arsenic	ug/l, diss	21.2	4.59
Antimony	ug/l, diss	<1.0	<1.0
Cadmium	ug/l, diss	<1.0	<0.1
Chromium	ug/l, diss	1.26	1.33
Copper	ug/l, diss	<2.0	<0.5
Lead	ug/l, diss	<1.0	<0.2
Manganese	ug/l, diss	481	43.2
Molybdenum	ug/l, diss	<5.0	<5.0
Mercury	ug/l, diss	<0.01	<0.01
Nickel	ug/l, diss	<2.0	1.2
Selenium	ug/l, diss	<1.0	<0.5
Silver	ug/l, diss	<1.0	<0.1
Zinc	ug/l, diss	<5.0	5.93
Potassium	mg/l, diss	5.24	1.89
Lab pH	s.u.	7.81	6.79
Field pH	s.u.	7.48	6.91
Acidity	mg/l, $CaCO_3$	<10.0	<10.0
Phosphorus	mg/l	0.0674	0.0317
Orthophosphat	mg/l	0.0282	0.0176
DOC	mg/l	29	8.86
Bicab Alkalinity	mg/l $CaCO_3$	239	179
Total Alkalinity	mg/l $CaCO_3$	239	179
Silica	mg/l	5.84	81.8
Chloride	mg/l	6.08	5.82
Fluoride	mg/l	0.181	0.252
Nitrate-N	mg/l as N	<0.1	<0.1
Nitrite-N	mg/l	<0.1	<0.1
Sulfate	mg/l	149	78.6
Sulfide	mg/l		<0.05
Lab Sp. Cond.	uS/cm	725	511
Field Sp. Cond.	uS/cm	623	518
TDS	mg/l	540	320
TSS	mg/l	<4.0	12
Hardness	mg/l	150	216
Field Temp	C	9.8	8.5

The findings of this evaluation indicate that the higher sulfate concentrations in the groundwater on the north side is likely due to the disturbed pyritic rock in the Pit 5 quarry area. The bedrock knob in the northwest corner of the

tailings facility may also contribute. Confirmation of the source of the sulfate in the Pit 5 area will be made by continuing the water quality monitoring program described in KGCMC, 2003.

On the south side, KGCMC's evaluation concluded that rock exposed at the Wide Corner area northeast of Tank 6 (Figure 3-14) contains pyritic zones that could account for the minor sulfate loading observed in the wells. This area has been covered with an engineered liner prior to tailings placement as part of the Southeast Expansion.

An evaluation of the west-side wells concluded that water in the shallow sands may have come into contact with water from Further Seep (see next section), pyritic rock and/or tailings prior to the 1996 slurry wall construction. Two possible sources for the elevated sulfate in the west-side bedrock wells are the bedrock knob near the northwest corner of the tailings pile and the northern terminus of the West Buttress slurry wall where it keys into bedrock. The influence of the higher sulfate concentrations appear to be localized, and there is an absence of a tailings contact water signature such as elevated metal levels, associated with these sulfate concentrations. Therefore, it is believed that the bentonite slurry walls and clay/silt sedimentary units are performing well with respect to capturing and preventing migration of tailings contact water. Confirmation will be made by obtaining additional water elevation data on either side of the slurry wall beneath the West Buttress as well as continuing water quality analyses for these sites.

3.8.2 Surface Water Quality

Surface water quality has been evaluated from FWMP samples taken from Tributary Creek downgradient from the tailings facility and Cannery Creek upgradient and downgradient from the existing tailings facility (Table 3-8)

A summary of surface water quality data from FWMP monitoring sites located on Cannery and Tributary Creeks is shown in Table 3-7.

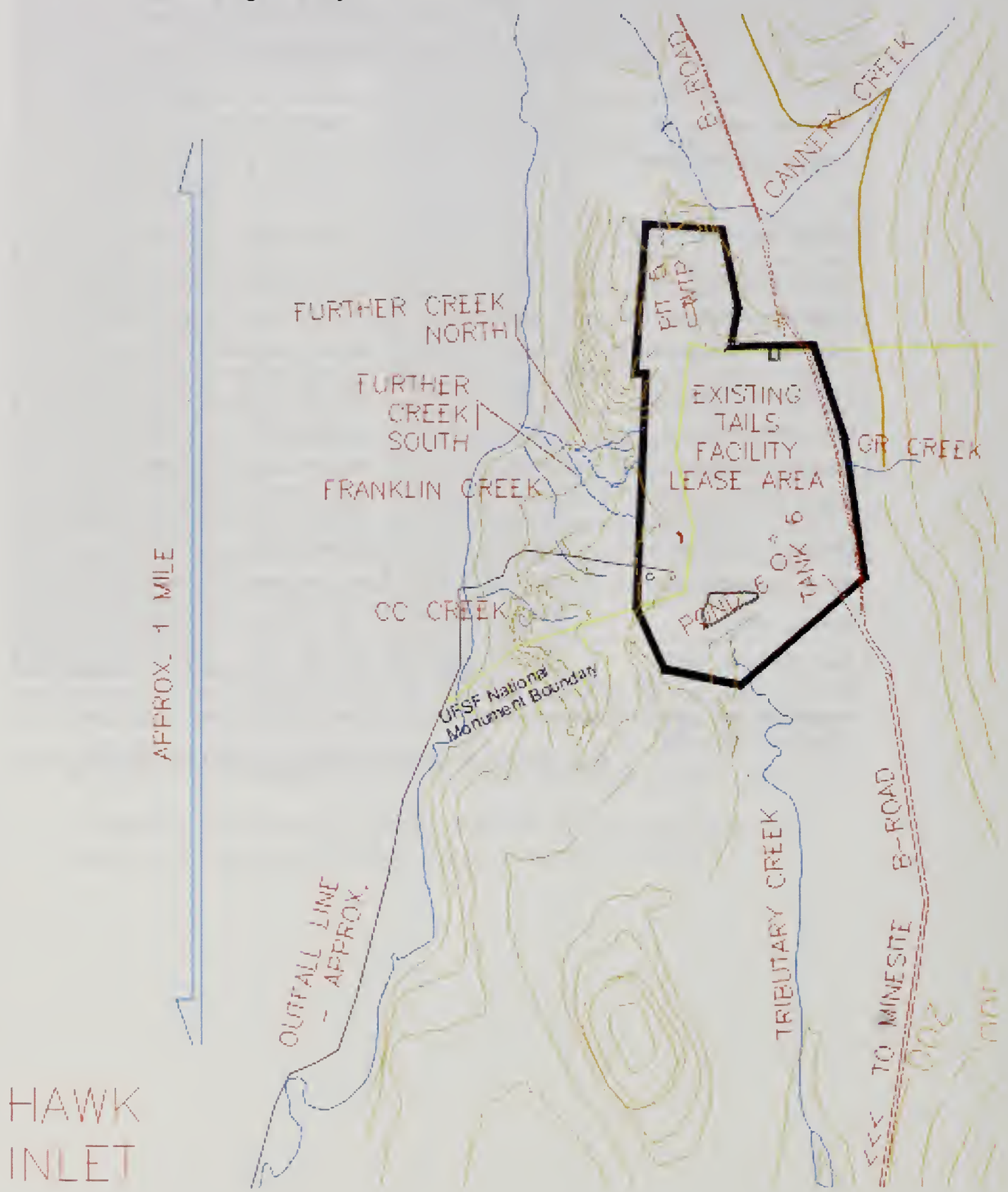
Table 3-7 Surface Water Quality – FWMP Sites

Analyte	FWMP #9 Tributary Creek (range, average)	FWMP #11 Cannery Creek (range, average)	FWMP #37 Upper Cannery Creek (range, average)
Total Alkalinity, mg/l	8-21, 13	7-31, 15	8.2-27, 14
Hardness, mg/l	23-159, 43	14-49, 33	14-39, 28
Conductivity, umhos/cm	33-150, 83	39-208, 72	36-133, 58
pH, s.u.	4.2-8, 6.6	6.6-7.4, 7.0	6.5-7.5, 7.1
Arsenic, dissolved, µg/l	ND-2, 0.025	All non detect	All non detect
Barium, dissolved, µg/l	ND-80, 3.0	All non detect	All non detect
Cadmium, dissolved, µg/l	ND-195, 5.87	ND-79, 1.36	ND-8, 0.44
Chromium, dissolved, µg/l	ND-10, 0.167	All non detect	All non detect
Copper, dissolved, µg/l	ND-55, 5.10	ND-40, 0.66	All non detect
Lead, dissolved, µg/l	ND-64, 2.08	ND-9, 0.37	ND-4.9, 0.16
Mercury, dissolved, µg/l	ND-0.7, 0.027	All non detect	All non detect
Nickel, dissolved, µg/l	ND-30, 6.55	ND-20, 0.50	All non detect
Selenium, dissolved, µg/l	ND-1.3, 0.0163	All non detect	ND-5.8, 0.1160
Silver, dissolved, µg/l	ND-31, 0.3864	All non detect	ND-10, 0.2000
Sulfate, mg/l	ND-52, 18.6	ND-13, 5.6	ND-7.1, 1.7
Zinc, dissolved, µg/l	ND-550, 38.48	ND-47, 5.82	ND-440, 15.38

ND = non detect. Detection limits have varied over the years. Current and past detection limits are listed in (KGCMC, 2001a). Data available for FWMP #9:1981-1993; FWMP # 11: 1981, 1990-1995; FWMP # 37: 1991-1993.

Data compiled from KGCMC water quality database, (KGCMC, 2003).

Figure 3-14 Upgradient and Downgradient Surface Water Flow from the Existing Tailings Facility



In general, surface water quality is characterized as having near-neutral pH, with low levels of dissolved metals and sulfate. Water quality data does not generally vary in Cannery Creek between the monitoring sites up- and downhill from the tailings facility. Surface water quality data indicate that AWQS have not been exceeded in Cannery Creek. The data from Tributary Creek reveal dissolved levels of cadmium, copper, mercury and zinc having values above the AWQS (reported as total recoverable) for these parameters. This is due to unusually high levels of these metals recorded on a few sampling dates in the late 1980s and 1990. Since 1990, these parameters have been analyzed at levels below AWQS. A low pH reading of 4.2 in November 1989 appears to be an anomalous value that is not associated with sulfate or metals having higher than normal values on that sampling date. The data set also indicates that upward trends in metal levels and sulfate, or downward trends in pH are not evident (SMI, 2000).

Water samples were collected from GR Creek in 2001 and analyzed for various parameters as part of the baseline studies conducted for this EIS. GR Creek is located to the east and uphill of the tailings pile. Table 3-8 shows a summary of the sampling results. Surface water quality is generally characterized as having near-neutral pH, with very low levels of dissolved metals and sulfate. Water quality in GR Creek is similar to that of Tributary Creek, which received flow directly from GR Creek prior to construction of the tailings pile.

Table 3-8 Surface Water Quality –GR Creek

Analyte	GR Creek 5/9/2001
Total Alkalinity, mg/l	8.0
Hardness, mg/l	13.7
Conductivity, umhos/cm	33
pH, s.u.	6.51
Arsenic, dissolved, µg/l	0.5
Barium, dissolved, µg/l	9.2
Cadmium, dissolved, mg/l	0.1
Chromium, dissolved, µg/l	15.5
Copper, dissolved, µg/l	4.7
Lead, dissolved, µg/l	0.2
Mercury, dissolved, µg/l	0.010
Nickel, dissolved, µg/l	2.15
Selenium, dissolved, µg/l	0.5
Silver, dissolved, µg/l	0.19
Sulfate, mg/l	2.6
Zinc, dissolved, µg/l	4.77

ND = non detect. *(EDE, 2002b)*

The Hawk Inlet catchment contains several small streams and seeps (Figure 3-14), which were also sampled during baseline data collection efforts in 2001. Samples were collected in Proffett/Franklin Creeks, Cannery Creek (2 sites), Further Creek (4 sites), Further Seep and the Duck Blind Drain. Table 3-9 presents a summary of water quality data for these surface water features around the tailings placement area.

Table 3-9 Surface Water Quality – Hawks Inlet Catchment

Analyte	Cannery Creek (2 sites)	Proffett/ Franklin Creek (2 sites)	Further Creek (4 sites)	Further Seep	Duck Blind Drain
Total Alkalinity, mg/l	ND	29-71	ND-13	ND	234
Hardness, mg/l	13-16	101-206	72-164	78-79	673
Conductivity, umhos/cm	21-29	198-382	131-303	342-377	1205
pH, s.u.	5.7-6.2	7.0-7.4	5.2-6.9	3.3	6.6
Arsenic, dissolved, µg/l	ND-0.6	ND	ND-2.1	ND-1.1	1.0
Barium, dissolved, µg/l	7.1-12.4	15.5-25.9	30.5-81.4	34.6-42.4	59
Cadmium, dissolved, µg/l	ND	ND	ND-0.6	0.2-0.3	ND
Chromium, dissolved, µg/l	1.6-19.5	ND-1.1	ND-19.8	1.1-1.9	ND
Copper, dissolved, µg/l	1.4-7.2	ND	1.5-7.1	4.3-4.9	ND
Lead, dissolved, µg/l	0.28-0.87	ND	0.7-4.3	1.9-3.6	ND
Mercury, dissolved, µg/l	ND	ND	ND	ND	ND
Nickel, dissolved, µg/l	1.2-2.3	ND	2.3-7.4	6.8-7.8	65.9
Selenium, dissolved, µg/l	ND-1.8	ND	ND-1.4	ND	1.3
Silver, dissolved, µg/l	0.2-0.7	ND	0.2-0.5	ND-0.16	ND
Sulfate, mg/l	0.8-1.5	63-140	43-149	98-118	496
Zinc, dissolved, µg/l	3.9-5.0	ND	29.3-209	65.4-71.8	97.3

ND = non detect. *(EDE, 2002b)*

Water quality in Further Creek, Further Seep, and Duck Blind Drain differ from surface water quality seen in Tributary, GR Creek, and Cannery Creeks. Lower pH and higher sulfate and zinc concentrations are evident; however, dissolved metal concentrations excepting zinc are within the range of other nearby streams. KGCMC notified the regulatory agencies of these water quality data, and proposed further characterization of the area in an action plan to the agencies dated September 6, 2001. This action plan provided data for a rigorous evaluation of the groundwater, surface water and seeps around

the tailings pile (EDE, 2002a), and sampling of both surface and groundwater sites continues.

Conclusions drawn from this evaluation indicate that the lower pH and higher sulfate waters do not show a tailings contact (i.e., interstitial) water component. Rather, the source(s) are believed to be pyritic material (quarry rock, production rock, or tailings) that lie outside the capture area for the slurry walls and clay/silt units underlying the tailings pile.

More specifically, the source of these anomalous waters in Further Seep area is believed to be residual effects of an old access road constructed in 1988 that contained pyritic rock. The road was located along a portion of the perimeter of the West Buttress. This road was removed during West Buttress and slurry wall construction. The acidity of the seep is not significantly higher than the acidity of typical muskeg water. The maximum concentrations of some metals such as copper, lead and zinc are below maximum background concentrations observed in the peat, sand, silt, and bedrock near the site (KGCMC, 2003). Observations of reduced impacts to vegetation in the seep area suggest that the source of acidity has been removed and that the quality of the seep is improving (EDE, 2002a, KGCMC, 2003). The North Fork South Spur of Further Creek has higher dissolved constituent loading than other locations within the Further Creek area. This is believed to be due to a thin veneer of tailings residue at the toe of the West Buttress. It is believed this residue accumulated during removal of the temporary PVC tailings cover in 1999. Another small exposure of tailings was identified in the bank of the Northwest Diversion Ditch located at the northwest corner of the West Buttress. This is also believed to be contributing to the Further Creek load. Routing the Northwest Diversion Ditch into the West Buttress Ditch (thus routing the water to the tailings water treatment system), and removing accessible tailings residue from the toe of the West Buttress Ditch, along with additional monitoring of these waters was completed by KGCMC in 2002.

The source of dissolved constituents in Proffett/Franklins Creek and Duck Blind Drain appears to be an access road and trench construction materials used for the NPDES discharge pipeline and associated utilities. This pipeline trench provides a preferential flow path for water along a portion of the western perimeter of the tailings pile. It is believed that the pyritic quarry rock used for pipe bedding and backfill contains carbonate mineralization but lacks zinc mineralization, which controls the water composition of Duck Blind Drain and ultimately Proffett/Franklins Creek. KGCMC has proposed routing the Duck Blind Drain directly to the NPDES discharge line, as well as continued monitoring of these waters.

3.8.3 Tailings Facility Operation

The mining process involves crushing ore and removing metal concentrates through a chemical flotation process. After the economically valuable metals are gone, the tailings are dewatered in a filter press. About half of the dry volume is then placed in the underground mine as backfill; the remaining half goes on the tailings pile.

3.8.4 Tailings and Rock Placement and Physical Characteristics

Materials are initially placed on the pile in discrete areas. During dry weather, tailings are distributed in thin layers and compacted to at least 90 percent of their Proctor density. The interior of the facility is accessed via temporary causeways that are constructed from crushed rock. The facility is designed and operated to keep the tailings moist to allow adequate compaction without excessive saturation. Excessive saturation prevents compaction and reduces material strength. Tailings placement techniques minimize the development of seepage and also insure that the pile is geotechnically stable.

The tailings, consisting of predominantly silt-sized particles, are delivered to the tailings facility by covered truck. Tailings are 76 to 96 percent finer than a 200 mesh (0.075 mm) sieve, and contain 5 to 13 percent clay. Tailings have 12 to 14 percent water by weight when they leave the mill. After placement, tailings have a dry bulk density of 2.15 g/cm^3 (134 lbs/cu. ft.) and a specific gravity of 3.6 g/cm^3 (EDE, 2002b). The porosity is approximately 40 percent, of which 64 to 75 percent is water-filled when initially placed in the pile. Consequently, the volumetric water content of the tailings, when placed, is 25.6 to 30 percent by volume.

Rock from Pit 5 is used for the construction of access roads, dams, and water containment/diversion facilities. Rock from the new quarry site in the SW expansion would also be used for these purposes under all action alternatives. Quarry rock with higher pyrite content is only used for internal tailings area road construction and other construction within the containment area of the tailings facility. Construction outside of the containment will only be done with rock with a low acidic potential (Zimmer, 2003).

3.8.5 Tailings Geochemical Properties

Tailings at the Greens Creek Mine were derived from zinc, silver, lead and gold-bearing rocks mined from deep underground. The ore is a massive sulfide deposit meaning that the tailings contain a large amount of pyrite, which, when exposed to oxygen, generates sulfuric acid, which causes an acidic pH. If acidic pH conditions develop in mining wastes (especially pH

less than 4.0), metals and sulfate contained in the material become more soluble than they are when the pH remains alkaline (above a pH of 7.0). Consequently, potentially acid-generating rock wastes are more likely to degrade water quality if waters that contact this rock are released and mix with receiving water.

Calcium carbonate and dolomite are also abundant in the host rocks for the Greens Creek deposit. Consequently, when the tailings weather, the acid formed by sulfide oxidation is neutralized by carbonate minerals. The relative abundance of pyrite and carbonates determines whether acidic conditions will form or the material will retain an alkaline pH because of the carbonates. The balance of acid-forming and acid-neutralizing minerals in mine waste is determined using the static test.

The static test (Sobek et al., 1978) quantifies the acid-generating and acid-neutralizing capacity of a sample. The acid-generating potential (AGP) is determined from the measured abundance of sulfide minerals in a sample while the acid-neutralizing potential (ANP) is based on the abundance of carbonate. The ANP minus the AGP is the net neutralization potential or NNP for a sample. Samples with NNP values less than –20 (measured in tons of $CaCO_3$ per 1,000 tons of material), have a risk of becoming acidic if they are exposed to oxygen (Miller et al., 1997). If the NNP is greater than +20 (or if the ratio of ANP to AGP is greater than 3.0 in some guidelines such as BC Research 1989), then materials are considered to be safe from ARD risk. The long-term behavior of materials with intermediate NNP values cannot be reliably determined with static tests alone.

Static testing of tailings from the Greens Creek deposit (Figure 3-15) indicates that they have the potential to become acidic. However, owing to the abundance of calcium carbonate and dolomite in the samples (generally ranging from 10 to 60 percent), a long period of weathering, estimated at more than 10 to 33 years in lab tests conducted on siliceous waste rock samples, would have to occur prior to development of acidic conditions. Before mining, the lag period for siliceous waste rock was estimated to be 22 to 33 years (Vos 1993). This estimate was based on the assumption that oxidation rates observed during 2 years of humidity cell and column tests would continue at the same rate indefinitely, and that acidic conditions would occur when all but 26 to 38 percent of the original carbonate had been removed. In a subsequent test, Vos (1994) removed carbonates by leaching with acid to determine the pore water chemistry that would form after dissolution of all carbonates within the siliceous waste rock. He estimated on the basis of this evaluation that acidification would not occur for more than 10.9 years, which would provide ample time for application of site closure technologies (e.g., the cover) to mitigate the ARD risk.

Vos (1991) also conducted geochemical evaluations of a tailings sample, which provided variable estimates of ARD risk. Static tests indicated that the tailings were potentially acid generating because of the abundance of pyritic sulfur. When the BC confirmation test was conducted in two ways, results indicated ARD risk to be "none" to "marginal." Humidity cell test results through 26 weeks were presented by Vos (1991). The tailings humidity cell and column tests were extended for 573 days as reported by Smith (1991). Based on the extended humidity cell testing, Smith concluded that the tailings were relatively unreactive, that the tailings were unlikely to generate acid, and even if any acid were generated it would be consumed within the tailings mass without being released.

An estimate of lag period in tailings was based on comparison to waste rock lag periods, and on modeling of the results of measured rates of pyrite oxidation in tailings kinetic tests. The evaluation of tailings conducted by Vos (1991) and evaluated by Smith (1991) indicated that the tailings may not become acidic, though the results were not internally consistent and some tests suggested a risk of ARD development. Recent grab samples of tailings (Figure 3-15) show that many samples have a lower NNP than the Vos tailings sample. Consequently, the overall tailings are more safely considered to have a risk of generating locally acidic conditions, especially near the surface where oxidation is more prevalent. Also, during operations the oxidation rate in tailings would likely be less than occurs in waste rock especially as long as new tailings, which inhibit the oxygen supply, are continually added to the pile. Consequently, the lag period in tailings is likely to be longer than in siliceous waste rock because the average tailings ANP (225 t/1,000 t) is greater than the ANP of siliceous waste rock (162 t/1,000 t), because of the slower intrinsic rate of oxidation observed in tailings kinetic tests, and because the oxygen supply is expected to be slower in tailings than in waste rock. It may be that the average lag period (before generation of acidic pH levels) for the operating tailings facility is in the range of 20 to 50 years. Appendix A contains a more detailed discussion of acid generation risk and shows that tailings seepage would not acidify during operations or for an indefinite period after closure because of the following:

- Surficial samples of tailings exposed for many years contain appreciable ANP;
- All paste pH values of tailings are near neutral;
- No low pH water has been collected in the wet wells;
- Even if tailings acidification occurred in a thin veneer on the tailings surface, the tailings' water would migrate through tens of feet of unoxidized and neutralizing material prior to release from the facility;

- The cover placed over the tailings pile at closure will nearly arrest oxygen diffusion into the pile; and
- Sulfate reduction processes, which create alkalinity, should occur in the pile for tens of years (or longer if carbon is added). The alkalinity from sulfate reduction will combine with the buffering effect of the unoxidized tailings to counteract acidity.

Reclamation and closure methods developed for the tailings facility are designed to slow or stop the weathering process so that acidification does not occur in the facility after closure. The overall tailings acidification risk is considered minimal. However, the data upon which this analysis is based are variable, and the underlying assumptions have a high degree of uncertainty, making this estimate subject to error. Although the conceptual model of tailings geochemistry assumes that acidification will not occur, a monitoring program is in place (KGCMC 2000) to identify incipient acidic conditions in the tailings facility and develop appropriate mitigation measures. Since acidification, if it occurs, is expected to occur near the surface of the tailings, surface application and incorporation of lime, limestone, or lime-stabilized sewage sludge should provide an effective acid control strategy.

Monitoring of the pH of water that has contacted tailings at Greens Creek (Figure 3-16, Figure 3-17) indicates that the carbonate minerals have maintained a near-neutral pH throughout the operation of the facility. The pH of water collected in the wet wells is discussed in Appendix A. Available data from the drains includes direct measurement of drain chemistry in 1995 (Figure 3-18) when the drains were exposed, and wet well chemistry (including contributions of tailings seepage, groundwater and runoff) measured subsequent to 1995 (Figure 3-19).

Figure 3-15 Kennecott Greens Creek Tailings Samples

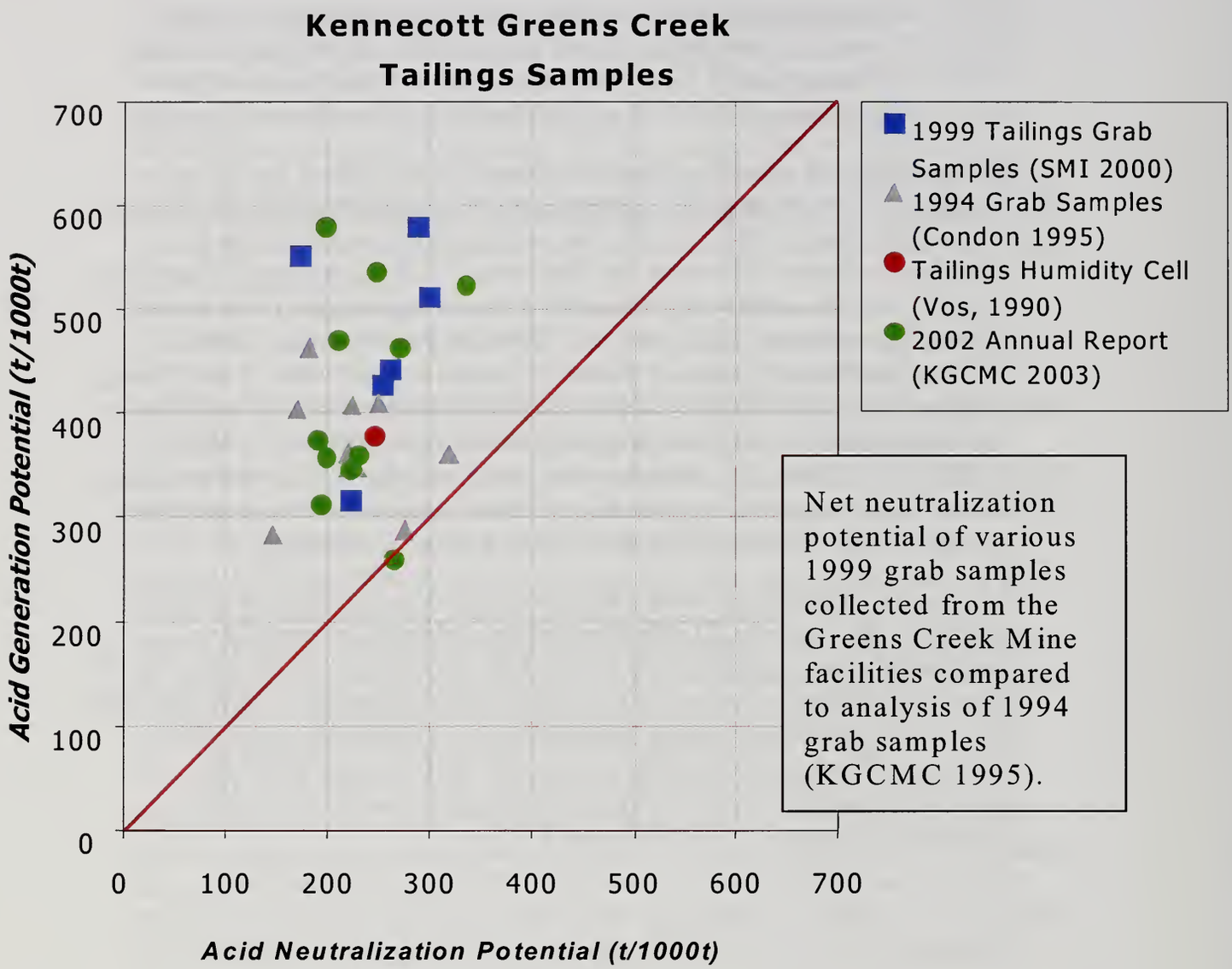


Figure 3-16 Paste pH and net neutralization potential of various grab samples collected from the Greens Creek Mine facilities.

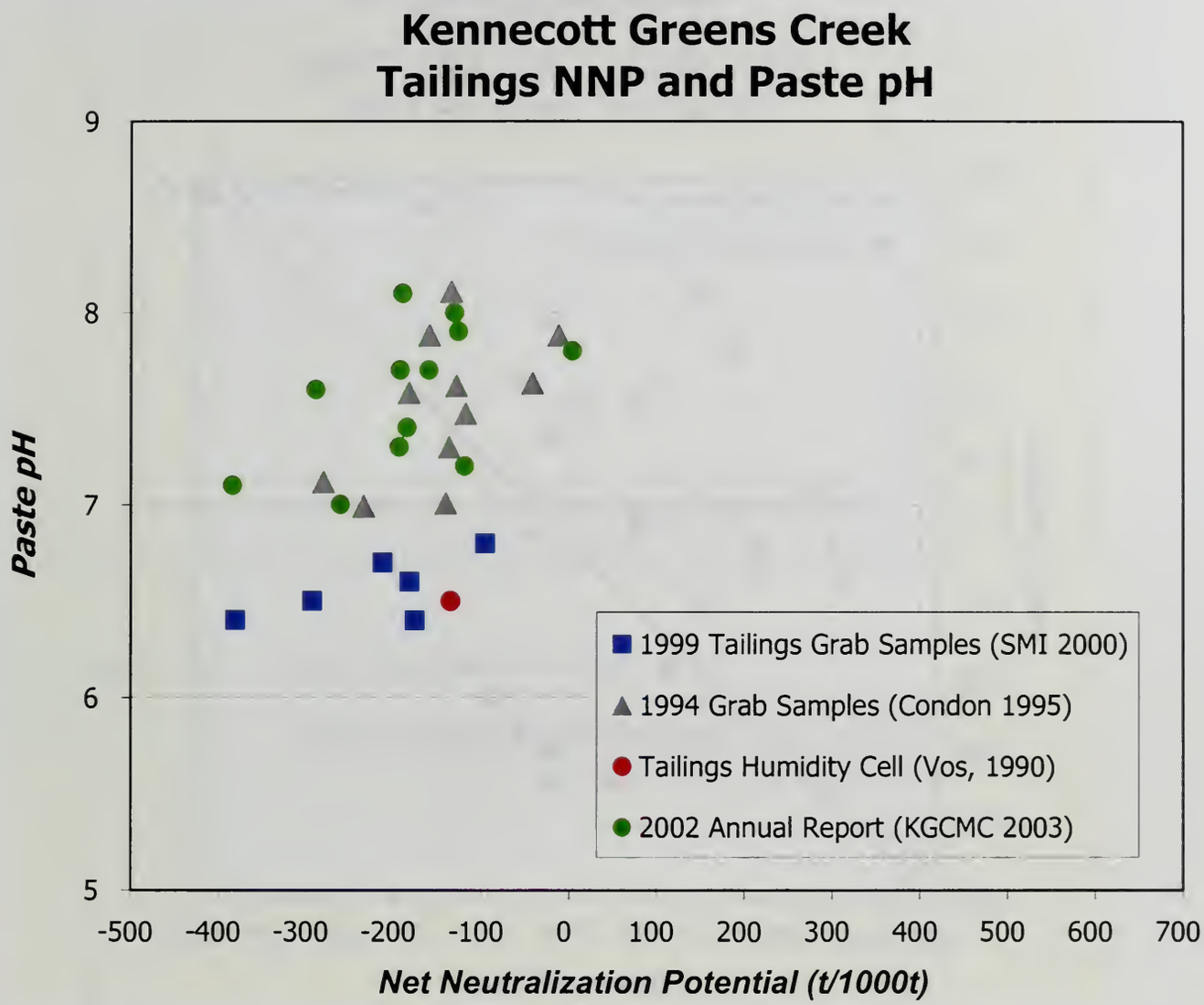


Figure 3-17 **Paste pH, humidity cell and net neutralization potential of various grab samples collected from the Greens Creek Mine facilities in 1989, 1994, 1999 and 2002.**

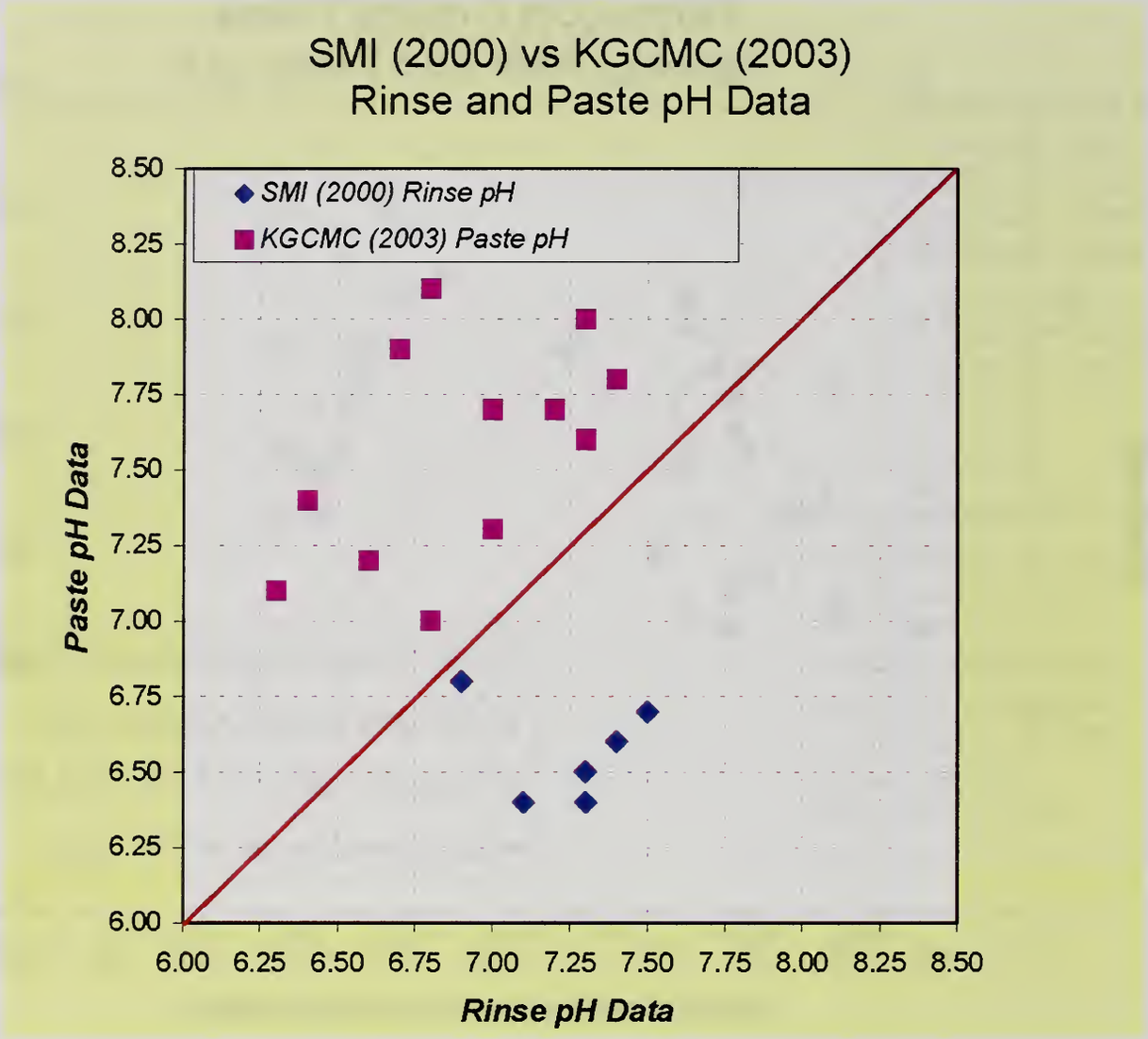


Figure 3-18 Tailings Drain Chemistry

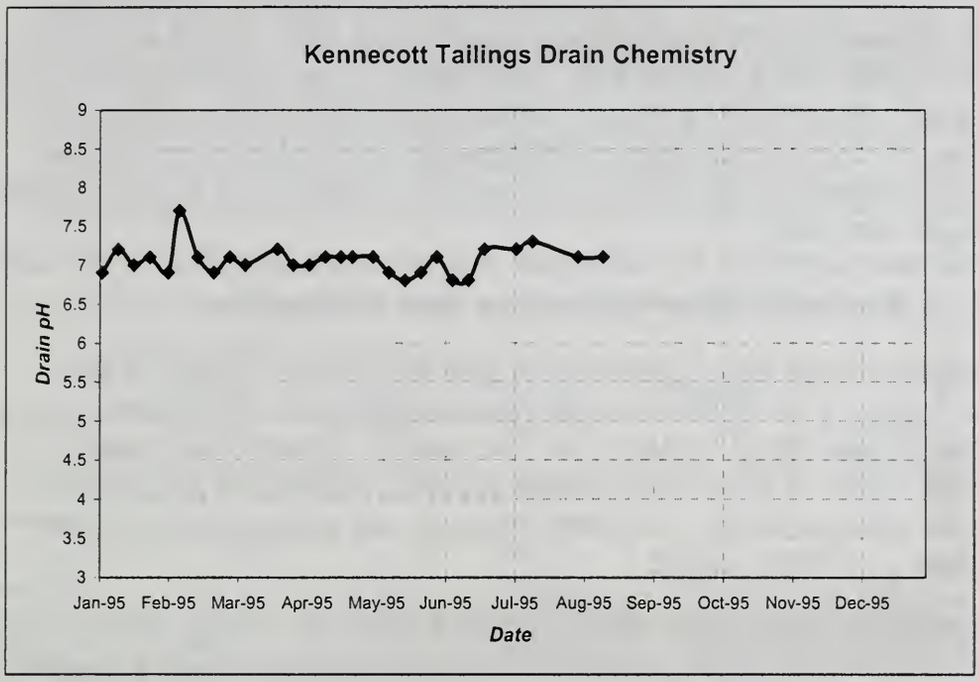
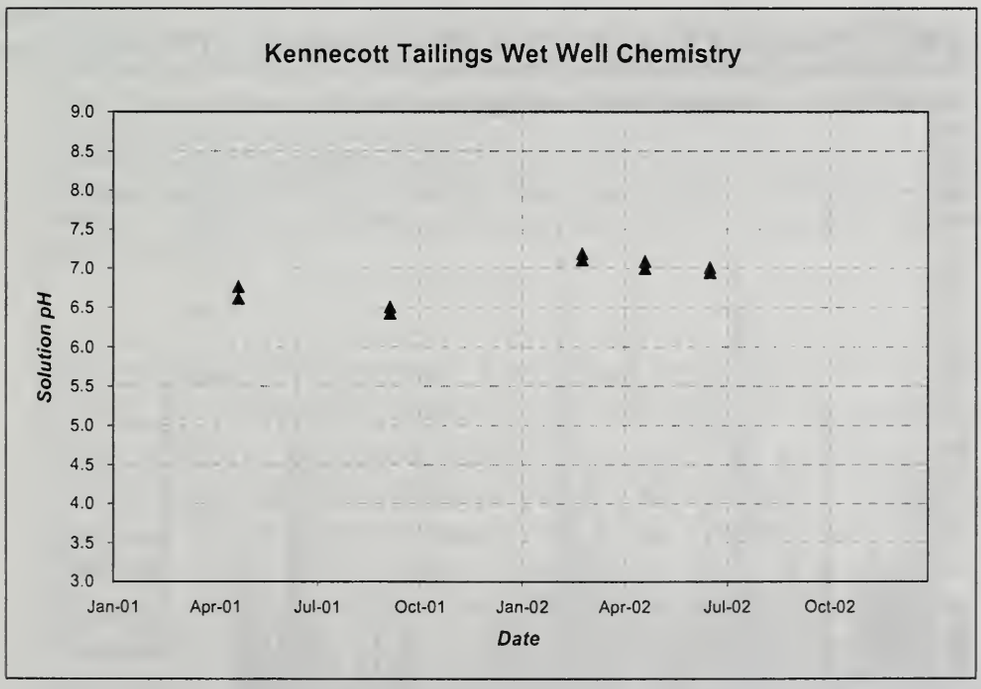


Figure 3-19 Tailings Wet Well Chemistry



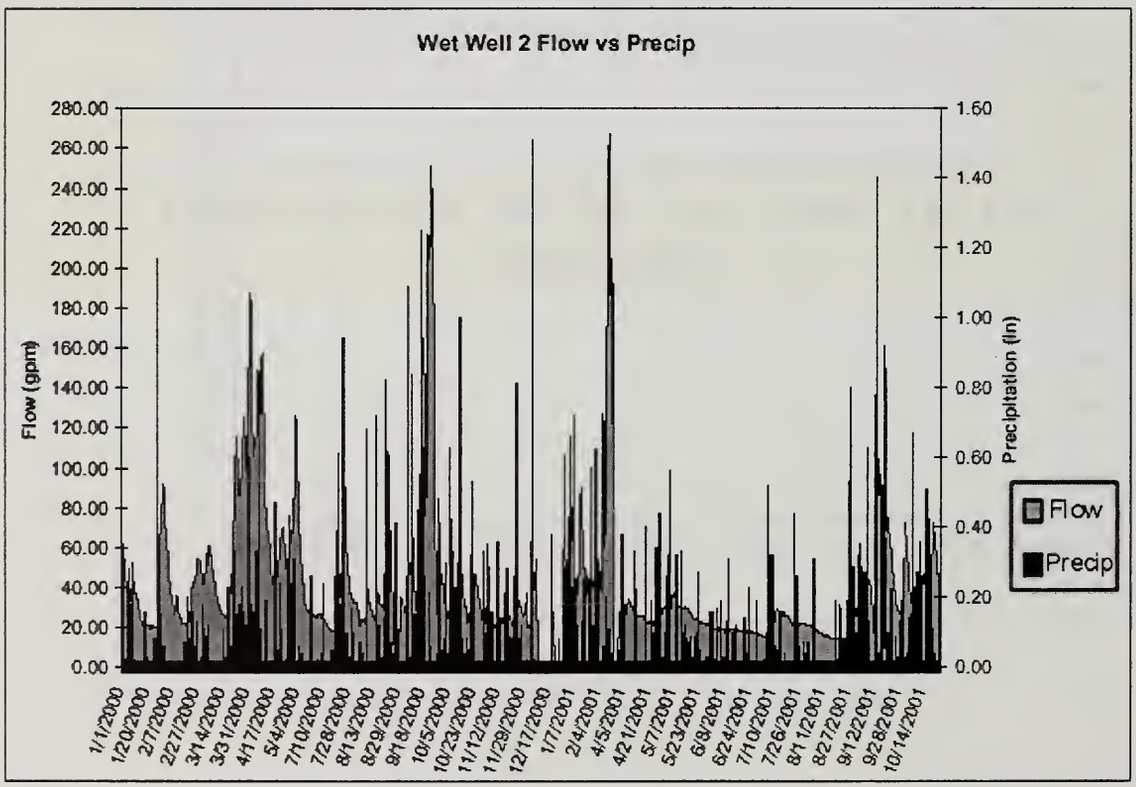
At the neutral pH conditions that are expected to prevail for tens of years in the Greens Creek tailings, oxidation may cause some metals to become soluble. Zinc, for example, is partially soluble even when the pH is alkaline, as in the Greens Creek tailings pile. Consequently, water leaching through or running off of the tailings pile may contain elevated zinc. The *contact water* (water in which the water quality is affected by chemical reaction with the tailings) also has a neutral pH, and elevated concentrations of sulfate, calcium, and magnesium ions.

3.8.6 Surface Water Diversion and Collection

Interception ditches were constructed around the uphill perimeter of the tailings facility to divert natural runoff around the facility. The ditches minimize the amount of contact water that must be collected and treated within the facility. Contact water, which includes surface and groundwater within the tailings facility, is collected, treated, and discharged into Hawk Inlet under an NPDES permit.

The quantity of surface water that is collected within the tailings facility varies through time. For example, records of water collected at wet well 2 (Figure 3-20), shows flow ranging from around 10 gpm during extended periods of dry weather, to over 200 gpm for short periods during a rain or snowmelt event.

Figure 3-20 Records of Flow and Precipitation Recorded at Wet Well 2



Using similar flow records for the two other wet wells, the average contribution of surface water, groundwater interception, and infiltration was found to be 48.3, 30.5, and 7.5 gpm, respectively (Table 3-10). The surface runoff is collected from approximately 32.7 acres, most of which is composed of tailings, with the remaining area comprised of ponds and land that is inside the diversion ditches but not covered by tailings. The quantity of surface runoff represents 54 percent of the average precipitation received at the site.

Table 3-10 Estimated average flow, baseflow, and runoff from wet wells #2 and #3.

Facility	Underdrain area (Acres)	Runoff area (acres)	Period of Record	Average Flow	Baseflow (gpm)	Runoff
Wet Well 2	14.6	12.2	11/9/97 to 10/23/01	77.9	55.6	22.3
Wet Well 3	3.7	3.7	10/28/00 to 10/23/01	10.1	6.9	3.3
Wet Well 4	4.3	4.3	1/20/01 to 3/31/01	13.3	nc	nc
				Average Flow	**Baseflow (in/yr)**	**Runoff**
Wet Well 2				103.3	73.7	29.6
Wet Well 3				52.9	35.9	17.0
Wet Well 4				nc	nc	nc

NOTE: The estimated contributions of runoff and baseflow based on historical wet well flows may not accurately reflect the effects of the recently-completed slurry cutoff wall constructed east of the tailings facility in 2000 and early 2001. Consequently, a baseflow separation was determined for combined flows in wet well #2 and #3 for the period from February 1, 2001 (after completion of the slurry wall) until November 2001, the end of the period of record.

Tailings Hydrologic Properties. The tailings present at the site are fine-grained, low permeability materials. Approximately 76-96 percent of the tailings are silt or clay-sized particles (less than 0.075 mm diameter). Despite their fine grain size, the tailings represent a separate water-bearing unit capable of yielding water to monitoring wells. A water table mound is present within the tailings, and has been shown to be responsive to changes in infiltration caused by surface management activities. Groundwater in the tailings discharges to a series of under-drains below the tailings that eventually route water to the water treatment plant. Two small seeps are noted in the tailings pile. A small drainage ditch on the north side of the repository seeps water that is collected and routed to the treatment plant. An intermittent small seep is also present on the southeast side of the pile. This water is also collected. Both seeps are thought to result from heterogeneity in pile materials

resulting from the presence of access road construction materials in the seep areas.

Groundwater Controls. Low permeability vertical barrier structures (bentonite slurry walls) were tied into underlying silt/clay deposits around the perimeter of the pile during construction, minimizing the potential for flow of upgradient groundwater into the tailings pile and the flow of tailings contact water out of containment to the west. Drains were constructed beneath the tailings facility to reduce hydraulic heads within the pile. These drains serve to maintain the geotechnical stability of the pile; additionally, they collect contact water that drains from the tailings. Groundwater within the tailings material and directly beneath the pile in the sand aquifer has a higher head (greater pressure) than water in the drains. This causes water to flow from the tailings into the drains under the pile and discharge to the sumps and wet wells and eventually to the water treatment plant.

Groundwater Flow in Tailings. Figure 3-12 shows a detailed representation of the complex groundwater flow systems at the site. Water levels in each layer are projected onto the cross section. Groundwater flows from areas of higher water levels to areas of lower water levels, so the figure shows that groundwater generally flows through the bedrock and till aquifers from east to west. Groundwater is mounded up in the tailings pile as a result of recharge from the surface of the pile and drains through the drain layer at the bottom of the pile. This drain layer (located approximately at the "peat top" location) also serves to receive water from upward flow from the bedrock and till layers beneath the pile.

Water levels monitored over time at the tailings facility have shown relatively small fluctuations throughout the year, except for wells installed in the tailings. These wells showed approximately a 10 to 12 foot drop in water level during the periods of time that a plastic cover was temporarily placed over the tailings from 1995 until 1997. Water levels have subsequently risen back to pre-cover levels. The groundwater mound in the tailings results from surface infiltration. It is not from lateral flow or the interception of upgradient (or underlying) groundwater. Nor is it from draindown of process water. Appendix A includes a conceptual model showing displacement of process waste.

3.8.7 Tailings Water Quality

The quality of water that contacts tailings, either surface runoff or water that infiltrates through the pile, is affected by the geochemical reactions that occur within the pile. These processes are important because they cause differences in water quality for contact water in various parts of the tailings facility and because they are likely to occur in the future, but at relative rates that may

change depending on how the tailings facility is reclaimed. Geochemical and hydrologic processes, as modified through facility reclamation, determine the post-closure quality of contact water.

Any water that flows on or through tailings is collectively called *contact water*. The geochemical interaction of contact water with tailings has been thoroughly investigated through monitoring programs conducted by KGCMC since it took over the mine and in various geochemical baseline studies. The chemistry of *process water* (water used to process the ore and to separate ore from tailings in the mill) is most readily understood in the context of the chemical evolution of water that flows on or through the tailings.

Process Water. Fresh tailings consist of the crushed solids from the ore zone that remain after removal of the ore concentrate. Additionally, the fresh tailings contain about 30 percent water by volume. The interstitial water in fresh tailings is comprised of process water. The chemistry of process water (Table 3-11) is the starting point from which contact water chemistry evolves. Process water has a neutral pH, and contains an abundance of calcium and sulfate ions and as discussed under Alternative C; process water contains carbon from the reagents used to process the ore. Process water also contains complex sulfur ions or "thiosalts" such as thiosulfate ($S_2O_3^{-2}$) and trithionate ($S_3O_6^{-2}$) that oxidize over a period of hours to days after exposure to oxygen. Oxidation of thiosalts produces acidity and forms sulfate (SO_4^{-2}).

Contact Water. Contact water includes interstitial water that flows out of the tailings as well as surface runoff from the pile. Seepage of contact water occurs either at the base of the tailings or in sidehill seeps. The majority of tailings seepage occurs at the base of the tailings where it is collected in underdrains and is directed to containment systems via pumping stations in wet wells. Sidehill seeps are also routed to the wet wells. Runoff is also collected at various locations and is pumped to containment ponds. The composition of various contact waters has been measured through monitoring programs and is described in more detail below.

Tailings Runoff. Soon after tailings are deposited, the chemistry of interstitial water changes in response to oxidation of thiosalts and sulfide minerals, each of which releases acid. Thiosalts oxidize relatively rapidly near the surface (in days to weeks) and more slowly at depth. Sulfides oxidize very slowly. When acid is released, it is neutralized by reaction with the naturally occurring dolomite and lesser amounts of limestone in the tailings. The reaction products of these processes include magnesium, calcium, and sulfate, with lesser amounts of zinc, and minor amounts of other metals. Ions may accumulate near the tailings surface as a result of evaporation during prolonged dry spells. Consequently, during the early stages of a runoff event, ion concentrations may be higher than after an extended wet period when

runoff becomes more diluted. The chemistry of runoff (Table 3-11) is similar to that found in the unsaturated zone (see below), except that runoff is somewhat lower in sulfate and magnesium and contains somewhat higher zinc. The higher average zinc concentration in runoff is thought to result from the higher concentration of zinc that is released from construction rocks used in the tailings area, rocks which themselves contain abundant zinc.

Table 3-11 Concentration of Selected Ions in Representative Contact Waters within the Tailings Facility

Parameter	Units	Process Water Filter press sampled 6/14/2001	Surface Runoff South Toe Ditch sampled 9/7/2001	Unsaturated Zone Lysimeter TSS99-01 sampled 12/7/1999	Saturated Zone Piezometer MW-TB2 sampled 4/25/2001	Wet Well 2 in Main Pile Underdrain sampled 9/7/2001
Common Ions		**Concentration**				
Total Alkalinity	mg/l $CaCO_3$	<5.0	110	38	357	252
Hardness	mg/l	999	1,830	NA	1,760	1,350
Lab Spec. Cond.	uS/cm	1,860	2,490	7,560	3,240	2,050
Lab pH	s.u.	7.86	7.55	6.56	7.79	6.5
Calcium (dissolved)	mg/l	386	427	1,720	182	343
Magnesium (dissolved)	mg/l	8.52	185	453	316	121
Sulfate	mg/l	660	1,800	2,290	1,820	1,130
Sulfide	mg/l	<0.05	NA	NA	7.0	NA
Trace Metals (dissolved)		**Concentration (dissolved)**				
Arsenic	µg/l	47.7	2.75	<10	16.8	21.2
Barium	µg/l	45.3	18.	NA	11.7	31.9
Cadmium	µg/l	<1	36.5	3.76	<0.1	<1
Chromium	µg/l	<1	1.58	NA	0.97	1.37
Copper	µg/l	<2	12.2	1,320	3.09	2.16
Lead	µg/l	123.	77.2	2.16 [1]	<0.2	1.43
Mercury	µg/l	<0.02	<0.01	NA	<0.01	<0.01
Nickel	µg/l	3.09	204	48.0	1.51	122
Selenium	µg/l	274.	4.27	244	1.34	2.44
Silver	µg/l	4.64	<1	NA	<0.1	<1
Zinc	µg/l	72.7	11,900	3,570	10.9	2,110

[1] The lead concentration for adjacent lysimeter SW-01-01 was used instead of the value of 16,900 µg/l lead measured in lysimeter TSS99-01 because the latter measurement probably results from contamination.

Tailings Interstitial Water. The chemical composition of dissolved ions in the interstitial tailings water gradually evolves in two ways. First, oxidation of thiosalts and sulfides creates an acidic environment that causes dolomite to be dissolved and soluble magnesium and sulfate to accumulate. Increased concentrations of soluble zinc and other metals may also accompany these increases in sulfate and magnesium ion concentrations. Additionally, the interstitial water is pushed downward into the tailings as meteoric water infiltrates into the pile. Assuming that the net infiltration rate into the pile is 3.5 to 7.0 gpm for a drainable porosity of 5 percent and 10 percent, respectively (EDE, 2002b), the rate of displacement of process water can be calculated to be 8 to 20 inches per year. It would require at least 45 years to

displace all process water from the thickest part of the pile (80 feet) if the flow is uniform, and the residual saturation is roughly 30 to 35 percent. The process water will be displaced faster in thinner parts of the tailings or if the tailings residual water content is lower. Tailings interstitial water is comprised of two distinct zones: the surface zone (which is unsaturated), and the deeper zone (which is saturated).

Unsaturated Zone Water. Through time, water in the unsaturated zone (Table 3-11) increases in sulfate (as a result of sulfide and thiosalt oxidation), and magnesium (as a result of dissolution of dolomite contained in the tailings). Additionally, soluble zinc also increases as a result of the sulfide oxidation, but the pH remains neutral.

Tailings Saturated Zone. Like the unsaturated zone, saturated zone water contains higher magnesium and sulfate than process water, indicating that thiosalt and sulfide oxidation has occurred (Table 3-11). Zinc and other metal concentrations in the saturated zone, however, are lower than in process water, and are much lower than in either the unsaturated zone or in runoff. The lower zinc levels are attributed to the process known as *sulfate reduction*. Organic compounds are added to the tailings from various sources, including flotation reagents and wastewater biosolids from the cannery housing facility. Certain microorganisms that degrade these organic compounds under anaerobic conditions reduce sulfate to sulfide and produce bicarbonate. The presence of sulfate reduction processes within the tailings is evident from the measurable levels of dissolved sulfide ion in all but one sample collected from the piezometers. Overall, 6 of 7 lab samples and 5 field samples from 3 piezometers and 1 monitoring well showed detectable sulfide levels (Appendix A) and all water samples contained low levels of zinc and nickel, which is consistent with sulfate reduction. The geochemical effects of sulfate reduction on metal concentrations, the likely persistence of sulfate reduction after facility closure, and the uniformity of sulfate reduction within the tailings, is discussed in the Appendix A.

Wet Well Contact Water. The chemistry of contact water collected in the wet wells within the tailings facility (Table 3-11) is affected by the proportions of various waters collected by the water management system. The largest proportion of water is comprised of surface runoff, with lesser amounts of tailings seepage (chemically similar to the saturated zone) and upwelling background groundwater collected in the drain system. All contact waters are currently collected and treated prior to discharge at a marine discharge point under jurisdiction of an NPDES discharge permit.

3.9 Wetlands

3.9.1 Introduction

An area of approximately 13,716 acres in the vicinity of the Greens Creek mine was examined for the presence of *jurisdictional wetlands*, and functional analysis of those wetlands. This larger area of the study was relevant because alternate disposal sites were among the alternatives initially considered (See Section 2.6.2). Of the total examined, an area of approximately 530 acres was found to exhibit jurisdictional wetland characteristics. (Jurisdictional Wetlands Survey and Functions and Values Analysis, 1994).

Functional analysis of the jurisdictional wetlands was conducted using a matrix of functions grouped into aquatic, terrestrial, and human use support categories. Each wetland function received a quantitative point total based on its overall score, effectiveness rating, and the number of contributing acres. The analysis identified a total of 148 acres of higher value wetlands within the study area, 186 acres of moderate value wetlands, and 197 acres of lower value wetlands.

3.9.2 Methodology

Jurisdictional wetland surveys and field verification were completed during 1990, 1991, and 1993 using criteria found in the 1987 *Corps of Engineers Wetlands: Delineation Manual* (COE, 1987). Several sources of existing data were identified and evaluated to aid in the wetland jurisdictional determination. These sources included the National Wetlands Inventory (NWI); the Chatham Area Integrated Resource Inventory (IRI) Mapping, Drill Logs and Geotechnical Surveys; Aerial Photography, Topographical Features, and As-Built Survey Data.

Field verification of jurisdictional wetland surveys was completed by analyzing 1/10th acre plots to verify or document significant changes from the preliminary mapping. Generally, information collected at each 1/10th acre plot included the following:

- Percent coverage of dominant plant species by strata (tree, shrub, herbaceous, bryophyte) and their wetland indicator status;
- Soil type and characteristics;
- Visible or readily apparent hydrologic characteristics;
- Physical characteristics such as slope, aspect, elevation, and landform;

- Global positioning system latitude and longitude coordinates; and
- Wildlife and fisheries habitat utilization notes.

Existing data were then correlated with field verification to arrive at final wetland jurisdictional determination mapping.

The wetland functions and values assessment used a point ranking system to evaluate most wetlands in the field verification area as well as other large wetland systems inside the aerial photograph coverage boundary. The method used assigns values ranging from 10 to 30 for each major wetland function identified (TTP, 1994b). These ratings, referred to as the "score," are based on documented regional wetland characteristics. The following were the wetland functions evaluated in the project area:

- *Aquatic Use Support*
  - Hydrologic Connection
  - Water Regime and Flood Control
  - Extent of Open Water
  - Water Quality: Sediment Retention
  - Water Quality: Erosion and Stability
  - Fish Habitat
- *Terrestrial Use Support*
  - Vegetation
  - Wildlife Habitat
  - Edge
- *Human Use Support*
  - Recreation
  - Aesthetics

An *effectiveness* rating, ranging from 0 to 1, is then applied to specifically address the wetland under evaluation. This rating is meant to reflect the area's current functional status or an assessment of its potential functional value after reclamation and restoration. In order to address size, scarcity, and potential impacts to wetlands within a specific watershed, the number of acres is also included in the assessment.

To complete the assessment, the functional score for each function of a wetland is established by multiplying the score by the effectiveness number, multiplied by the acres. Each functional score is then added to arrive at a final

combined score for the wetland. Those wetlands with scores greater than 225 receive *high value* ratings, those with scores from 176 to 225 receive *moderate value* ratings, and those with scores of 175 or below received *low value* ratings.

3.9.3 Jurisdictional Wetlands

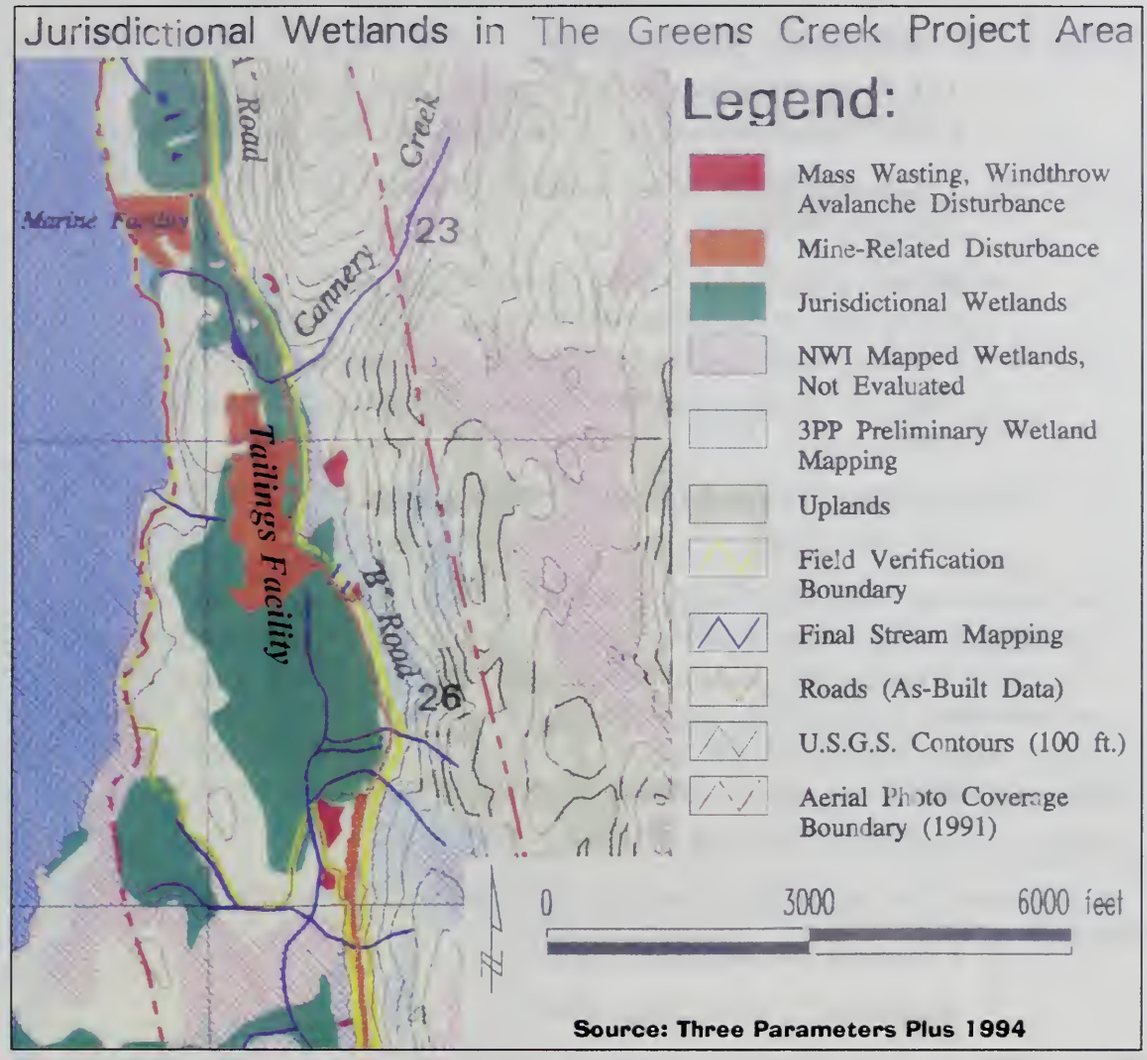
Aerial photos were taken of a larger area, surrounding the project area (Figure 3-21). Approximately 530 acres of land that exhibit jurisdictional wetland characteristics were identified within this larger area. These wetlands were found to meet the criteria of the COE 1987 Manual and are presumed to meet the regulatory definition of waters of the U.S. and to be subject to Section 404 of the Clean Water Act.

Typically, wetlands within the survey area were located along small stream and ravines, and on benches, lowlands, and floodplains. Wetlands in the study area could be broadly classified into four types: riparian (NWI class Palustrine forested seasonally flooded), tall-sedge muskeg and short-sedge muskeg (NWI class Palustrine persistent emergent saturated to seasonally flooded), and forested wetlands (NWI class Palustrine forested saturated). The most abundant wetlands within the study area were forested wetlands, which are approximately 34% of all wetland types. Short-sedge wetlands are least abundant in the study area with approximately 8.5%. Riparian wetlands are considered those wetlands adjacent streams that are within the stream floodplain. Estuarine and previously disturbed wetlands in the study area were not evaluated. Riparian areas in SE AK are primarily non-wetland, soils are not hydric, and the plants there are not considered hydrophytic.

The existing mine roads and facilities are shown as mine disturbance on Figure 3-21. Some of these impact jurisdictional wetlands. The acreage of those existing wetland disturbances is not shown on permits for the facilities, and is unknown at this time. It is anticipated that the new 404(b)(1) application will be attached to the FEIS as an appendix and will reflect these figures.

As with wetlands, surface waters (Figure 3-22) are usually considered "waters of the United States" and are, therefore, within the COE regulatory jurisdiction. Buffer strips shown on Figure 3-22 indicate the probable width of riparian wetlands along each stream. The riparian wetland acreages are included in the total wetland acreage.

Figure 3-21 Jurisdictional Wetlands



3.9.4 Functions and Values of Wetlands

The functions and values of most wetlands in the study area were evaluated using methods described above (For readers interested in wetlands, we urge you to read Jurisdictional Wetlands Survey and Functions and Values Analysis, 1994 (TPP, 1994a), contained in the planning record and on the web, with particular attention to the sections on riparian wetlands). For the analysis and evaluation, wetlands were broadly classified into several types. These broad types were also identified using the classification of Wetlands and Deepwater Habitats of the United States (Cowardin et. al, 1979), and Forest Service Integrated Resource Inventory (IRI) Plant Association classification system (TPP, 1994a). The wetland types evaluated include the following categories:

- **Riparian Wetlands** (National Wetlands Inventory [NWI] Palustrine forested seasonally flooded; Western hemlock, vaccinium spp. Skunk cabbage);
- **Tall-Sedge Muskegs** (NWI Palustrine Emergent Wetland, Fresh Water, Mixosaline; IRI Tufted Club Rush/bog Kalmia);
- **Tall-Sedge/Short-Sedge complex Mosaics** (NWI Palustrine Emergent Wetland);
- **Forested Wetlands** (NWI Forested Wetland Needle-leaf Evergreen. all Non-tidal Regimes Except Permanently Flooded, Fresh Water; IRI Mixed conifer/Blueberry/Skunk Cabbage, Western Hemlock/Blueberry/Skunk Cabbage, and others; and
- **Forested Wetland/Upland Complex Mosaics** (No NWI or IRI Equivalent).

Wetlands with combined average scores of 226 points or higher were classified as higher value wetlands. Wetlands with combined average scores of 176 to 225 points received a moderate value wetland rating. Those with a combined average score less than 176 points received a lower value wetland rating. Higher value wetlands are generally found in riparian zones (along streams), while lower value wetlands are found in forested areas. Figure 3-23 identifies wetland values in the Greens Creek Project Area.

In summary, the following are acreages and values for each wetland type:

- **Forested,** 185 acres, low value;
- **Riparian,** 71 acres, high value;
- **Forested Wetland/Upland Complex Mosaic,** 71 acres, low value;
- **Short Sedge,** 45 acres, moderate value; and
- **Tall Sedge,** 16 acres, moderate value.

Figure 3-22 Surface Waters

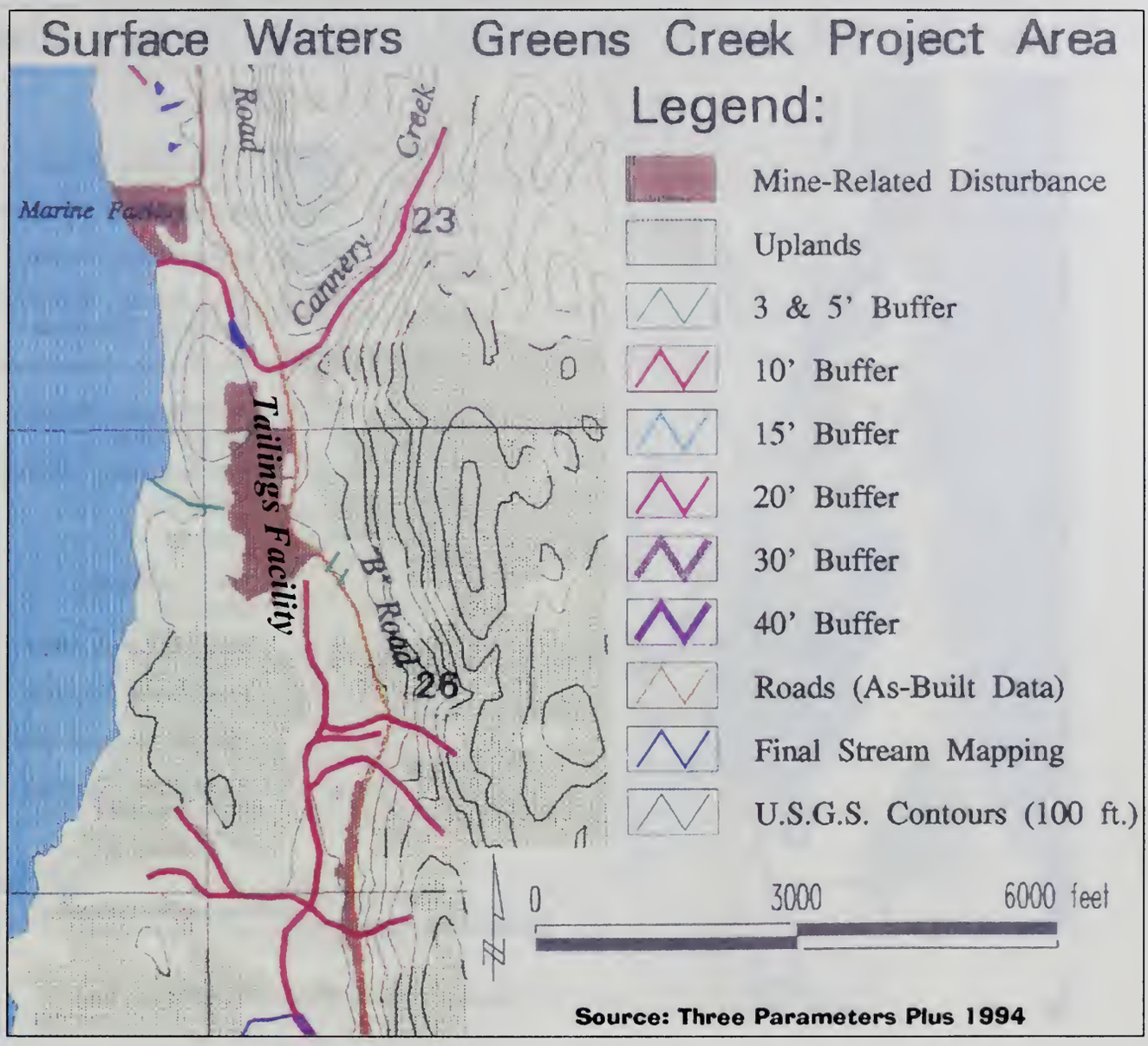
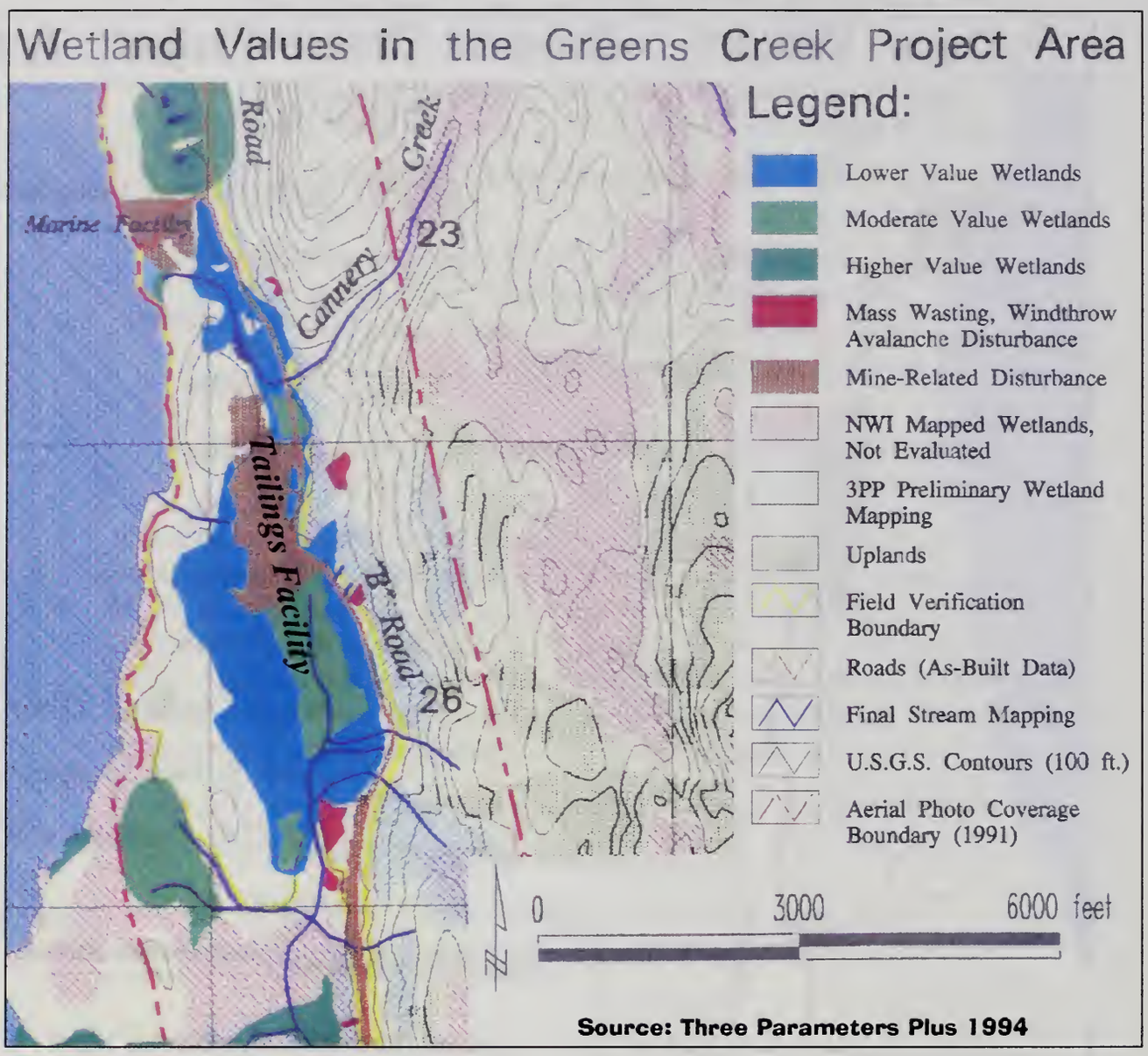


Figure 3-23 Wetlands Values in the Greens Creek Project Area



3.10 Vegetation

As with most of Admiralty Island, the vegetation surrounding the proposed tailings area consists of hemlock – spruce forest interspersed with a mosaic of non-forested plant communities, including peat wetlands, shrub wetlands, and sedge meadows.

The proposed mining project does not include plans for commercial timber sales, other than for timber that will be removed to clear the area for tailings expansion or other mine facilities.

No threatened or endangered plant species known to occur in the project area. An Alaska Region Sensitive Plant study concluded that no sensitive plant species were identified for the project area (See Section 3.12 and Dunn, 2003).

Forest Service plant association types found in the project area (See Section 3.9 and Jurisdictional Wetlands Survey and Functions and Values Analysis, 1994) include:

- Western Hemlock/Blueberry,
- Western Hemlock/Blueberry/Spinulose Shield Fern,
- Western Hemlock/Blueberry-Devil's Club, Deep Soils,
- Western Hemlock/Blueberry-Devil's Club, Shallow Soils,
- Western Hemlock/Devil's Club,
- Western Hemlock/Devil's Club/Skunk Cabbage,
- Western Hemlock/Blueberry/Skunk Cabbage,
- Mixed Conifer/Blueberry,
- Mixed Conifer/Blueberry/Skunk Cabbage,
- Mixed Conifer/Skunk Cabbage-Lady Fern, and
- Mixed Conifer/Vaccinium/Deer Cabbage.

In addition, five types of wetlands were identified in the project area, including:

- Riparian Wetlands,
- Tall-sedge Muskegs,
- Tall-sedge/Short-sedge Muskegs,
- Forested Wetlands, and
- Forested Wetland/Upland Complex Mosaics.

3.11 Wildlife

The Forest Plan identified management indicator species (MIS). These are vertebrate or invertebrate species whose response to land management activities can be used to predict the likely response of other species with similar habitat requirements. For the Forest Plan, 13 management indicator species were identified, with more attention given to those MIS species having special management concerns (brown bear, marten, Sitka black-tailed deer, and gray wolf). The gray (or Alexander Archipelago) wolf does not inhabit

Admiralty Island. Marten are discussed below under furbearers. MIS birds are discussed in their respective sections.

3.11.1 Brown Bear

Brown bear probably achieve higher populations on Admiralty Island than anywhere else in Southeast Alaska. Based on mark-resight estimates, brown bear densities in a 344 square kilometer area centered on Hawk Inlet and the Greens Creek watershed averaged 40 bears during 1986-87 (Schoen and Beier, 1990) and 46 bears in 1993 (Titus and Beier, 1993). While virtually all of the project area is bear habitat, three specific habitats are of primary importance (Figure 3-1). These are the coastal beach fringes, grass meadows, and adjacent forest used during the spring and early summer; the creek bottoms and adjacent banks and forests from tidewater upstream to the limit of salmon spawning used during mid to late summer; and the denning areas used during winter. Beginning in early May and extending until approximately mid-June, the coastal beach fringe and grass meadows provide food and cover for bears. The important items during this period include grasses, sedges, forbs, carrion, and available marine organisms.

The late-summer season has been identified as the most critical or limiting period for brown bear. During this season, many brown bears concentrate along low-elevation valley bottoms and salmon streams. These are often the same areas of highest human use and most intense resource development activities. During this season, brown bears use a variety of habitats, with estuaries and riparian areas having the highest habitat value. Streams and rivers that produce anadromous fish have a higher value for brown bears than resident fish streams. Brown bears have not been identified as a species requiring minimum patch sizes of a particular habitat type. They are not known to have specific vegetation corridor requirements, as they travel and disperse through a variety of terrain and vegetative conditions. (Forest Plan, 1997)

The creek bottoms and adjacent banks and forest, especially old growth that is adjacent to salmon spawning streams, are of great importance to brown bear from approximately mid-July until mid-September. In the project area, Greens Creek, Zinc Creek, and the lower stretch of Tributary Creek are especially important.

Spawning salmon provide a major part of many bears' summer food. Remains of bear-eaten salmon carcasses can be found from tidewater to as far upstream as salmon spawn. When not actively feeding on salmon, bears still remain relatively close to the streams.

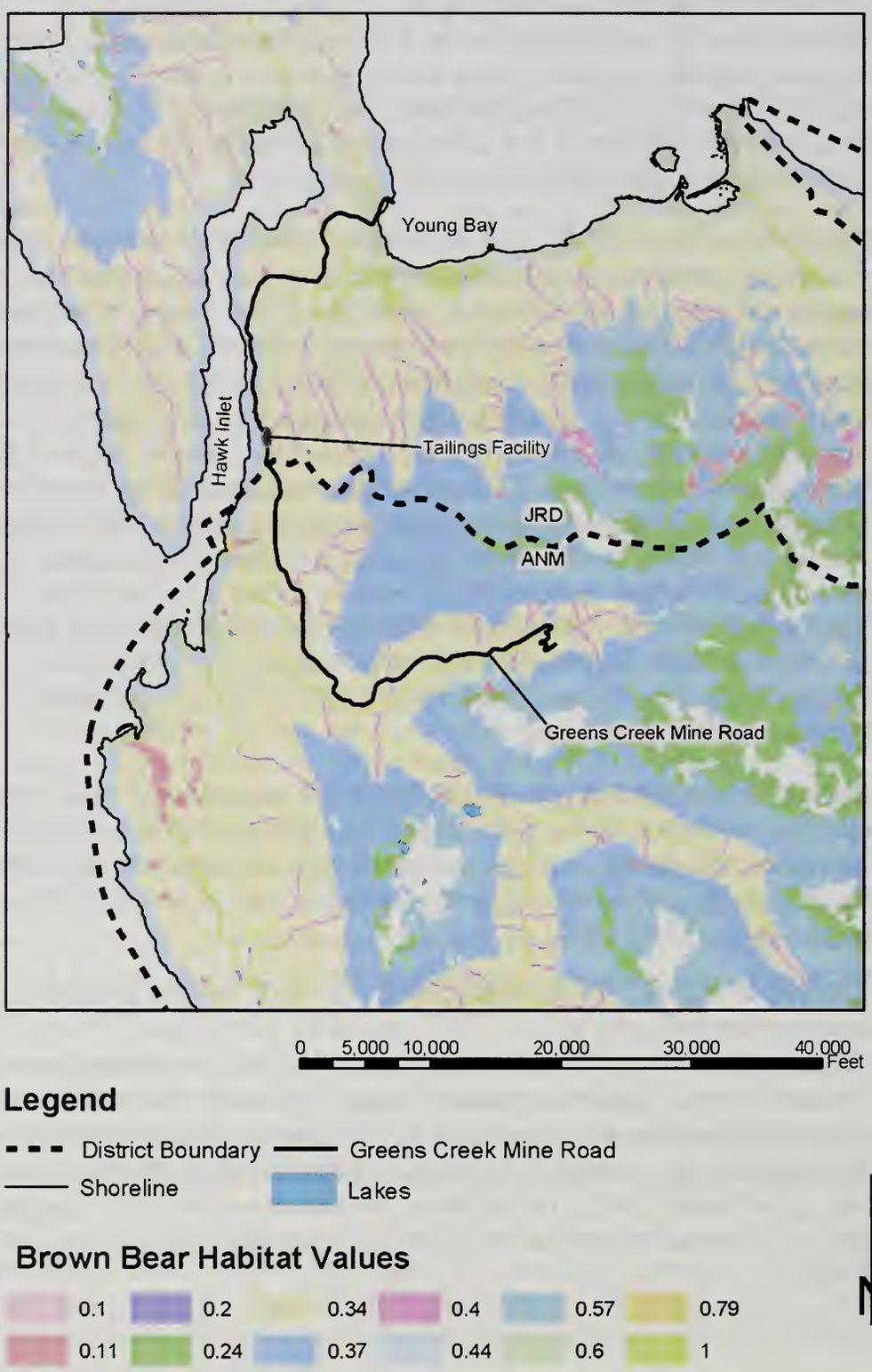
Brown bear tagging and monitoring studies were undertaken in 1981 by the Alaska Department of Fish and Game (ADF&G) to establish a baseline for documenting the effects of logging and mining in Southeast Alaska, and to develop ways for minimizing brown bear conflicts with humans during project construction and operation. These studies provided baseline population estimates for the project area and were continued through 1993 when the mine closed for three years due to low metals prices. No follow up population study has been conducted since the mine restarted in 1996.

The results of the 1981-89 ADF&G studies, which included mine construction and initial operations, concluded in general that it did not appear that the home ranges and seasonal distribution of adult brown bears were substantially influenced in the short term by development activities, with the exception of denning distribution (Schoen and Beier, 1990). The authors thought that while bears remained in their traditional home ranges, they shifted away from the immediate vicinity of construction activity and then moved closer to the road when activity was reduced. Their observations suggested that bears on the Greens Creek Delta, particularly young bears, were becoming habituated to aircraft and vehicle traffic noise associated with mine development. In the short term, then, they believed direct impacts to bears had been minimized. They noted, however, these results reflected short-term effects of development activities on bears, and that it would be premature to conclude that development of the Greens Creek Mine would have minimal impacts on the local brown bear population.

None of the habitat that will be lost due to this project is in beach fringe or otherwise critical to bears. The ADF&G has advised that it is the activities associated with human activity associated with mining activities, rather than the minimal loss of habitat connected with the mine, that poses a potential to impact bears (Titus, 2002).

The map in Figure 3-24 displays habitat capability indexes generated by the management indicator species (MIS) model for brown bear (USDA, FS 1993). These indexes represent relative measures of brown bear habitat in and around the project area. The index numbers range from 1.0 to 0.0, with 1.0 representing optimum habitat value and 0.0 representing no habitat value. By dividing the index number into thirds, a subjective high, medium, low value rating can be assigned to the habitats. As shown on the map, the tailings facility is located in medium value brown bear habitat (indexes of 0.34 – 0.44).

Figure 3-24 Brown Bear Habitat Distribution



USDA, FS, 2003, TNF GIS database

During the first year of observation, Schoen and Beier (1990) found that the mean distance radio-collared bears denned from the mine site was 3.4 km. The next year they denned significantly farther from the mine site (11.7 km). They assumed these bears were most influenced by mine site activities, including intensive helicopter traffic. Schoen and Beier (1990) were not aware of any bears killed by construction workers or mine operators and attributed that to rigidly enforced policies to avoid bear problems. All food garbage is kept indoors until incinerated daily and littering or feeding of wildlife is prohibited. Mine personnel brought to the island on company furnished transportation (boat or plane) are not permitted to carry firearms, or to hunt or hike on site. They must return to the area on their own time by private or commercial means for such activities just like anyone else. With the exception of the camp caretaker, who is the only permanent resident at the Hawk Inlet Cannery camp facility, fishing by company personnel also is prohibited (Oelklaus, 2001).

Four bear deaths in the project area may be attributed to project-related activities. A bear was shot by an early exploration camp crew in the 1978 – 1980 timeframe when it became progressively more aggressive, invading the camp area and chasing workers (Oelklaus, 2001). In May of 1992, a radio-collared two-year old male that was habituated to humans was killed by a mine vehicle on the B Road near the Zinc Creek Bridge (Titus and Beier, 1993; Oelklaus, 2001). In the summer of 1993, a female became very aggressive around the Hawk Inlet Cannery camp, chasing people into buildings and breaking into the kitchen and other buildings for food. When continued use of rubber shotgun slugs and "crackers" became progressively less effective, the bear was shot (Oelklaus, 2001). In the summer of 1999, a small bear was killed by a concentrate haul truck near 4.9 mile of the B Road after it bolted from the surrounding forest. (Oelklaus, 2001).

Bears are regularly seen on or near the mine road system. Because workers are not allowed to leave the road system or project facilities (mine entrance, mill, tailings disposal area, cannery/office complex), other sightings in the project area are less frequent. Bears are regularly seen by geologists, however, during summer surface exploration activities throughout the Greens Creek drainage basin, as well as further north on the peninsula between Hawk Inlet and Young Bay. Bear are usually observed beginning in May, and they are seen several times a week through June. Observations drop off by mid-July along the road system, except near streams where salmon spawning areas occur within sight of the road, primarily along lower Tributary Creek. In September and October bears appear to travel more, but observations fall to 1-3 per week unless a bear travels along a road corridor where it can be seen all day (Oelklaus, 2001).

3.11.2 Sitka Black-Tailed Deer

Sitka black-tailed deer are found throughout Admiralty Island and are common in the project area. Most make distinct seasonal movements between winter and summer ranges, while the remainder show substantial overlap between winter and summer ranges. While many deer may make the classically described seasonal movements from winter range in the lower elevation coastal old-growth forests, to summer range in the subalpine and alpine areas, and return to lower elevations again the following winter, the elevational distribution of deer between and within years is highly variable (Habitat Relationships of Sitka Black-Tailed Deer, USDA Forest Service, 1986).

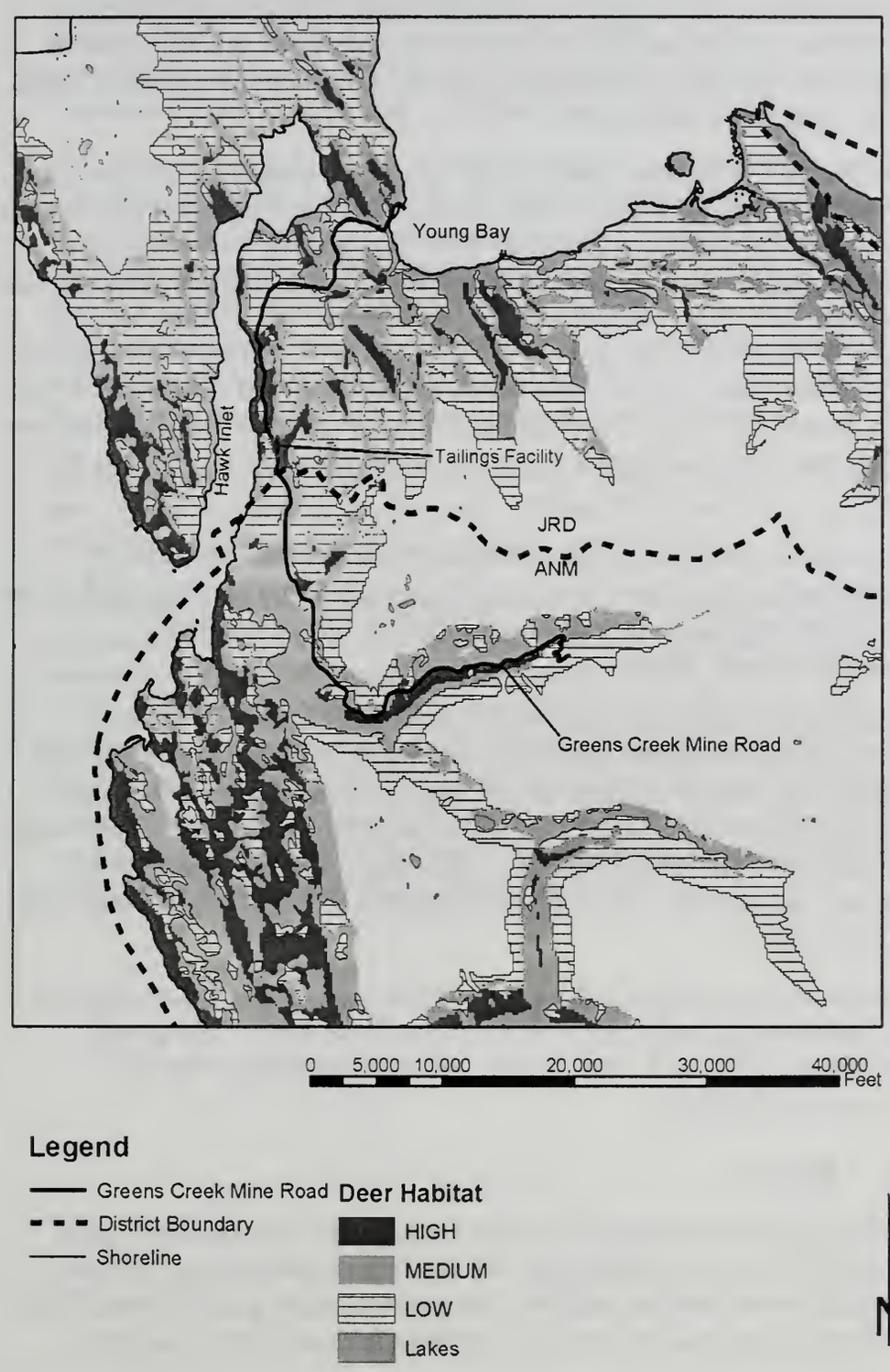
The high volume old-growth forest areas below 1,000 feet are important habitat for deer, particularly during the critical winter period. Of particular importance are south or west facing slopes that have ground dogwood, berry bushes, and goldthreads understory association. Figure 3-25 shows the relatively important deer winter habitat within the project area. Deer winter habitat with relatively H (high) importance indicates high population densities of deer, M (moderate) indicating moderate population densities and L (low) indicating low population densities accordingly.

The habitat that would be lost due to expansion of the pile is primarily muskeg meadows with some timbered areas along the parameter which is low to relative unimportant deer winter habitat.

The ADF&G has studied deer populations, habitat preferences, and home range on northern Admiralty Island for several years, but no studies to assess the effects of the mine on deer populations have been initiated because deer populations do not appear to be affected (USDA, FS 1992). Deer are frequently observed near mine facilities, and deer congregate along the Greens Creek road system, feeding on the reclamation grasses during spring, summer, and fall. Little deer use of the Greens Creek road system is noticed in the winter when snow covers the grasses because the animals seem to retreat beneath the mature forest canopy (Oelklaus, 2001).

Deer/vehicle collisions along the road system occur approximately 3 to 5 times a year despite an observed speed limit and radio communication between drivers alerting them to animal sightings as traffic moves along the road system. The year 2000, however, was unusual in that approximately 10 to 12 deer accidents occurred (Oelklaus, 2001).

Figure 3-25 Deer Habitat Distribution



USDA, FS, 2003, TNF GIS database

3.11.3 Furbearers

Furbearers found in the project area include marten, mink, river otter, and beaver. Marten occupy coniferous forests; the other three species are more water-oriented. All are year-round residents of the Hawk Inlet, Greens Creek, and Young Bay areas (USDA, FS 1983).

The densities of the various furbearers in the project area are not known, nor is the extent of trapping activity. ADF&G does not have furbearer populations or trapping results specific to the study area. The drainages of Greens and Zinc Creeks and the shoreline of Hawk Inlet and Young Bay are prime habitat for mink and river otter, and they are frequently observed in those areas as well as in the vicinity of the cannery (USDA, FS 1983). Beavers are regularly found on most streams and in some ponds in the vicinity of the Greens Creek facilities, including Greens Creek and along the A road. The hemlock-spruce forest that dominates the project area is typical marten habitat (USDA, FS 1983).

The river otter is found along the coastal and inland waters throughout Southeast Alaska. They have been recorded on mainland localities and, in the Alexander Archipelago from Admiralty Island to Wrangell Island (MacDonald & Cook, 1999).

River otters are closely associated with coastal and freshwater aquatic environments and the immediately adjacent upland habitats within 100-500 feet of the coast. Beach characteristics affect the availability of food and cover. The highest value habitats are found in old-growth forest habitat with high canopy cover, large diameter trees and snags. These areas provide denning and rearing sites. Early forest successional stages are of lower value (Forest Plan, 1997).

The affected forest area that will be used for the tailings expansion does not provide high quality habitat for river otter due to the lack of old-growth characteristics. Snags and down woody debris are lacking in the site (MacDonald, et al, 1999).

3.11.4 Birds

Five MIS upland bird species live in the Tongass and may be found in the project area. They are the bald eagle, the red-breasted sapsucker, the hairy woodpecker, brown creeper, and the Vancouver Canada goose (Forest Plan, 1997). There is suitable habitat for all of these species in the lease area.

Vancouver Canada geese are found throughout Southeast Alaska with an estimated resident population of 10,000 birds in the northern portion of Southeast Alaska. This population is relatively non-migratory, moving locally

between nesting, brood rearing, molting and wintering ground. Vancouver Canada geese use wetlands (forested and non-forested) in the estuary, riparian, and upland areas of the forest (Forest Plan 1997). Habitat is specifically provided for under the Waterfowl Standards & Guidelines in the Forest Plan. Expansion of the tailings will not affect Vancouver Canada goose habitat.

The Queen Charlotte subspecies of the northern goshawk and ospreys though not MIS species are listed as Alaska Region Sensitive Species and are likely to occur in the vicinity of the proposed expansion project. The Queen Charlotte subspecies of the northern goshawk nests high in old growth forest trees and uses the same areas for nesting year after year, although not necessarily the same nest. No high volume old growth is immediately adjacent to the project site. No nests have been identified in the immediate vicinity of the proposed project by any resource agency or mine staff.

Osprey eat fish almost exclusively and nest close to water. No osprey nests have been identified on the east side of Hawk Inlet in the vicinity of the proposed project by any resource agency or mine staff.

The American bald eagle is given special protection under the Bald and Golden Eagle Protection Act. Admiralty Island supports the highest documented density of breeding bald eagles in North America (USDA, FS 1983). In Southeast Alaska, bald eagles typically nest in large Sitka spruce trees in stands of old-growth timber within about 650 feet of salt water (Hodges and Robards, 1982). Figure 3-26 shows the location of documented eagle nests along the shore in Hawk Inlet, and along the coast, approximately one mile, on either side of the inlet. The closest known eagle nest to the tailings pile is more than one-half mile away.

Figure 3-26 Bald Eagle Nest Tree Sites

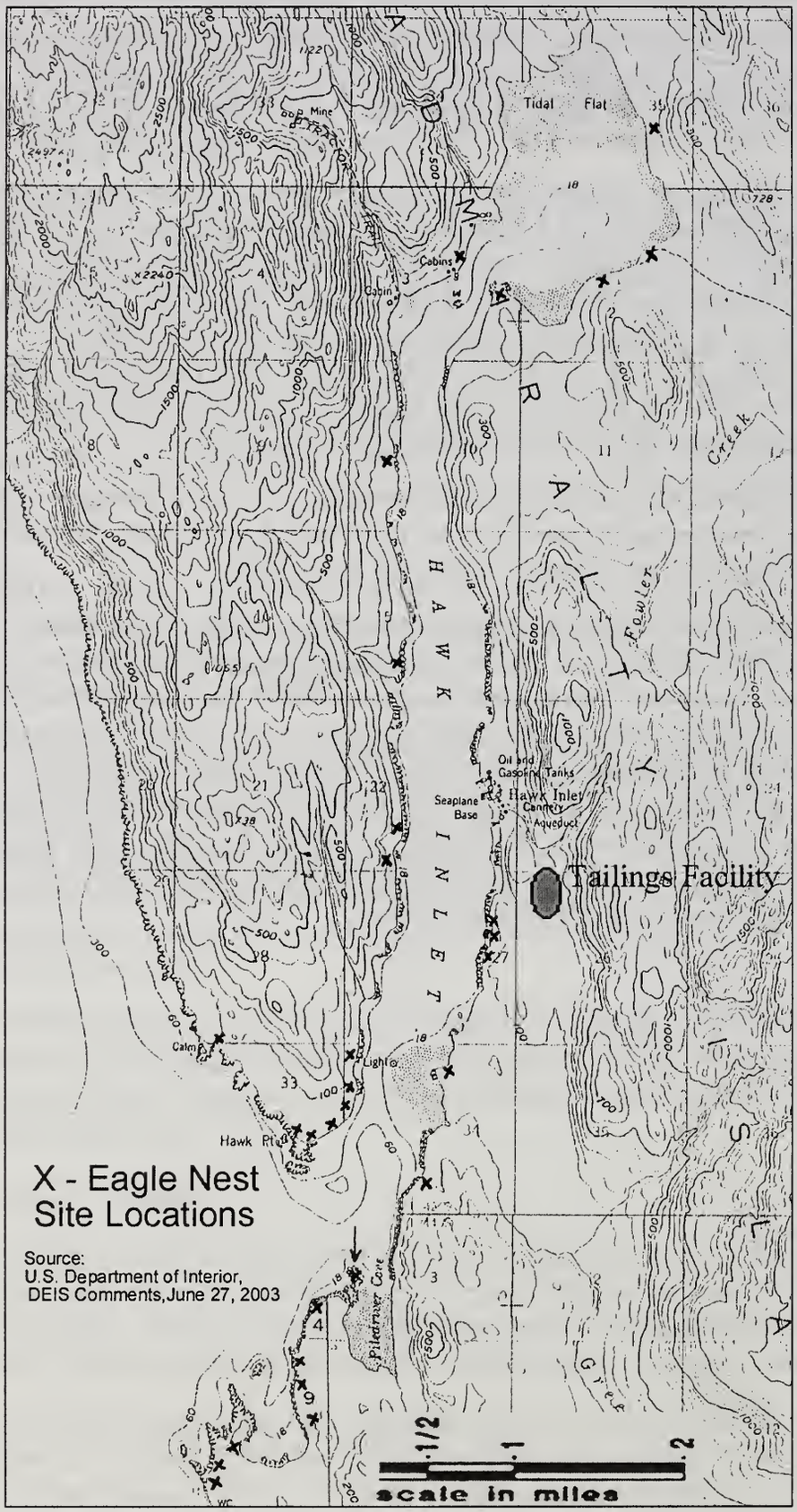


Table 3-12 Priority Species that are Known to Occur in Mature/Oldgrowth Spruce-Hemlock Habitats

Common Name	Scientific Name	Occurrence[a]	Abundance[b]	Habitat Preference
Blue Grouse	*Dendragapus obscurus*	B, W	common	xx*
Western Screech-Owl	*Otus kennicottii*	B, W	uncommon	xx#
Vaux's Swift	*Chaetura vauxi*	M, B*	uncommon	x#
Rufous Hummingbird	*Selasphorus rufus*	M, B	common	xx*
Red-breasted Sapsucker	*Sphyrapicus rubber*	B	abundant	xx*
Pacific-slope Flycatcher	*Empidonax difficilis*	B	common	xx*
Steller's Jay	*Cyanocitta stelleri*	B, W	abundant	xx*
Northwestern Crow	*Corvus caurinus*	B, W	abundant	xx*
Chestnut-backed Chickadee	*Poecile rufescens*	B, W	abundant	xx*
Golden-crowned Kinglet	*Regulus satrapa*	B, W	common	xx#
Varied Thrush	*Ixoreus naevius*	M, B, W	abundant	xx*
Townsend's Warbler	*Dendroica townsendi*	B	common	xx*
Blackpoll Warbler	*Dendroica striata*	M	rare[1]	xx+
Northern Goshawk	*Accipiter gentilis laingi*	B, W	uncommon	xx*
Marbled Murrelet	*Brachyramphus marmoratus*	B, W	common	xx*
Olive-sided Flycatcher	*Contopus cooperi*	B	uncommon	x
Western Wood-pewee	*Contopus sordidulus*	B	uncommon	x
Hammond's Flycatcher	*Empidonax hammondii*	B	uncommon	x
MacGillivray's Warbler	*Oporornis tolmiei*	B	uncommon	x
Golden-crowned Sparrow	*Zonotrichia atricapilla*	M, B	common	x
Northern Shrike	*Lanius exubitor*	W	uncommon	x
Gray-cheeked Thrush	*Catharus minimus*	B	rare	x

[a]Occurence - B=Breeding W=Winter M=Migration *=no record, but thought to breed
[b]Abundance - 1=migration only
[c]Habitat Preference - Primary pref. = xx; secondary pref. = x; minor habitat pref's not indicated;*=breeding, #=probable breeding, +=possible breeding*

Birds of Conservation Concern and Priority Species

The Migratory Bird Treaty Act of 1918 (amended in 1936 and 1972) prohibits the taking of migratory birds, unless authorized by the Secretary of Interior. Because migratory birds do not recognize political boundaries, treaties were

developed between the United States, Great Britain and Japan in order to manage the resource. The law provides the primary mechanism to regulate waterfowl hunting seasons and bag limits, but the scope of the authority is not limited to hunting.

Over 100 species of birds migrate from the lower forty-eight states, Central, and South America to nesting, breeding, and rearing grounds in Alaska. Most of the birds fly to the interior or northern Alaska and only pass through Southeast Alaska on their way to the breeding grounds. Some species do breed and nest in Southeast Alaska and are likely to use habitats in the Green's Creek area.

The term "Birds of Conservation Concern" is a U.S. Fish and Wildlife Service designation (USFWS, 2002). They are called "Priority Species" in the Landbird Conservation Plan for Alaska Biogeographic Regions (BPIF, 1999). Executive Order 13186 directs federal agencies to take conservation actions for birds and consider effects in the NEPA process.

3.11.5 Waterfowl / Shorebirds

The portion of the project area of primary significance to waterfowl is the estuary at the head of Hawk Inlet. It is used throughout the summer by many duck species of divers and dabblers, and is an important resting area for dabblers during fall and spring migrations. Shorebirds, gulls, and eagles also use the estuary and associated mud flats extensively. Waterfowl and other birds also frequently use the triangle-shaped area at the mouth of Hawk Inlet that includes Piledriver Cove, Hawk Point, and the Greens Creek/Zinc Creek Delta. A third area of importance is the southern portion of Young Bay, which would not be affected by the proposed project. All of these areas are three to four miles distant from the proposed project area.

The grass meadow areas near the mouths of Greens and Zinc Creeks and other creeks in the project area provide habitat for many species of shorebirds and waterfowl during summer and fall. Harlequin ducks may use the Greens Creek meadow for breeding. Dabbling ducks, primarily Pintails, are common in the still water areas in the Greens Creek and Fowler Creek meadows in late summer and fall. Migrating waterfowl use ponds and beaver impoundments in the project area for feeding, resting, and probably for breeding.

The marbled murrelet is a waterfowl species designated as a species of concern in the Forest Plan, 1997. Marbled murrelets are widely distributed across marine waters in Southeast Alaska. They spend nearly all their time at sea, coming to land only for nesting activities. Only six nests have been found in Southeast Alaska. Four of the nests were located in old-growth trees on wide, moss covered branches. The others were found on the ground, also in

old-growth forest. The available data from dawn watch surveys suggests that marbled murrelet activity is greater in old-growth forests, particularly in higher wood volume forests than in other habitats in Southeast Alaska. Ground-nesting may be important in some areas, particularly in previously glaciated terrain (USDA, FS 1996).

3.11.6 Marine Mammals

Nine marine mammal species occur in or near Hawk Inlet: Steller sea lion, northern sea otter, harbor seal, killer whale, gray whale, humpback whale, minke whale, harbor porpoise, and Dall's porpoise. Of these the Steller sea lion, humpback whale and northern sea otter are listed or may soon be listed under the US Endangered Species Act. These three species are discussed in Section 3.12, Threatened and Endangered Species.

Harbor Seal

Harbor seal are the most common marine mammal in Southeast Alaska inside waters and are the most frequently observed marine mammal in the Hawk Inlet area. The Southeast Alaska harbor seal population has been stable or increasing in the past 15 years, at about 37,450 animals (1998 estimate). Harbor seal females in Southeast Alaska typically give birth to one pup per year from about mid-May to mid-June. Harbor seals molt during late summer and early fall. During this time, they eat less and spend more time hauled out (Matthews, 1996).

Although capable of long range movements, harbor seals are not considered migratory. Adult harbor seals exhibit strong site fidelity for breeding and haulout sites. Tagging studies indicate that they spend 57% of each day hauled out (Matthews, 1996).

Harbor seals in Southeast Alaska are opportunistic feeders, eating a wide variety of fish and invertebrates. Their diet varies seasonally, regionally, and probably annually (Jemison, 2002). Studies indicate that pollock, arrowtooth flounder, shrimp, herring, eulachon, salmon, octopus, rockfish, blennies and skates are most commonly consumed by harbor seals in Southeast Alaskan waters (Mathews, 1996). All of these prey species occur in Hawk Inlet (ADF&G 2002; Holland et al. 1981; OIO & RTEC 1998).

Harbor seal are common at Hawk Point where small groups frequently haul out. At least two haul-out sites are located within one mile of the Greens Creek delta. When the salmon are running in Greens Creek and Zinc Creek, seals feed inside the Inlet. In addition to the preferred prey species listed above, they may also forage on herring, codfish, and crab when salmon are not running. Foraging opportunities in lower Hawk Inlet are limited due to strong tidal currents at the sill. It is estimated that seals are unlikely to be near

the outfall discharge except for two hours of a 24-hour period, during slack tide.

Other Marine Mammals – Habitat Uses within Hawk Inlet

Killer whales (*Orcinus orca)* have been observed within Hawk Inlet waters. They frequent Hawk Point where seals are abundant throughout the summer months, likely preying on seals or their pups. During migrations, both the "resident", fish-eating killer whale and the "non-resident", mammal-eating killer whale likely forage in the mouth of Hawk Inlet and Chatham Strait. OIO (1996) reported a sighting frequency of 5 percent for killer whales in the vicinity of Hawk Inlet.

Gray whales (*Eschirichtius robustus*) have been recorded in Chatham Strait, but no records of sightings have been found of gray whales inside the entrance to Hawk Inlet. Minke whales (*Balaenopterus acutorostrata*) are rare in Chatham Strait, and OIO (1996) reported a sighting frequency of 4 percent in the vicinity of Hawk Inlet. Mining staff have no records of minke whale within Hawk Inlet.

Both harbor porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*) are found in the vicinity. Although they are most often sighted in Chatham Strait, they also are seen inside the Inlet. OIO (1996) reported a sighting frequency of 7 percent for harbor porpoise and 3 percent for Dall's porpoise inside of Hawk Inlet.

Hawk Inlet supports fish and invertebrates sought by these marine mammals (See Section 3.13). Because of the high current velocities found in shallow sill areas at the entrance to Hawk Inlet, whales and porpoises are most likely to pass through the mouth of the Inlet and are not likely to feed in the area during most of the tidal cycle. There is no documentation of critical life history phases of any marine mammal occurring within Hawk Inlet. Hawk Inlet may intermittently support marine mammal feeding or resting needs, but none are considered residents of Hawk Inlet.

Table 3-13 Marine Mammals Occurring in the Vicinity of Hawk Inlet

Species	Presence in Hawk Inlet	Habitat uses in Hawk Inlet	Status
Steller sea lion	Common	Transit, foraging	Threatened under ESA
Harbor seal	Common	Transit, foraging,	N/a
Harbor porpoise	Uncommon	Transit -?	N/a
Dall's porpoise	Rare	Unknown	N/a
Killer whale	Uncommon	Transit, foraging	N/a
Humpback whale	Common	Transit/foraging	Endangered under ESA
Gray whale	Rare	Unknown	N/a
Minke whale	Rare	Unknown	N/a
Northern sea otter	None confirmed	Unknown	Northern stock under ESA review

Number of animals observed in one year in Hawk Inlet: Rare < 5 Uncommon 5-20 Common >20 Abundant >100

3.12 Threatened, Endangered, and Alaska Region Sensitive Species

3.12.1 Birds and Terrestrial Mammals

According to the U.S. Fish and Wildlife Service (USF&WS) there are no threatened, endangered, or Alaska Region sensitive listed birds or terrestrial mammals in the project area to be affected by the proposed action (Grossman, 2001).

The USF&WS has received a petition to list the Kittlitz's murrelet as an Endangered Species. The petition also requests that critical habitat be designated for the species. This small diving seabird breeds only in certain sections of coastal Alaska and to a limited extent in the Russian Far East. The largest known populations occur in Southeast and Southcoastal Alaska. Sometimes referred to as the "glacier murrelet", the Kittlitz's murrelet forages almost exclusively at the face of tidewater glaciers or near the outflow of glacier streams, and nests in alpine areas in bare patches among the ice and snow. The Sawyer and South Sawyer Glaciers are the tidewater glaciers closest to the project area. These glaciers are approximately 60 miles southeast of the project area on the mainland. The Brady Glacier is the next closest tidewater glacier approximately 65 miles northwest of the project area on the mainland. There are no tidewater glaciers in the Greens Creek project area.

3.12.2 Plants

The only plant federally listed or proposed by the USFWS in Alaska is *Polystichum aleuticum*, which is endangered. It is only known from Adak and is not expected to occur in the Tongass National Forest (Forest Plan, 1997). During 2001, field surveys were conducted throughout the project area to document the occurrence of any Alaska Region sensitive plant species within the vicinity of the Kennecott Greens Creek proposed expansion (Hasenjager, 2001). Consultation with the Regional Forest Botanist concluded that 8 sensitive plant species had potential to occur within the project study area. Those species and habitats are: Norberg arnica (*Arnica lessingii* ssp. *norbergii*), Goose-grass sedge (*Carex lenticularis* var. *dolia*), Davy mannagrass (*Glyceria leptostachya*), Wright filmy fern (*Hymenophyllum wrightii*), Truncate quillwort (*Isoetes truncata*), Loose-flowered bluegrass (*Poa laxiflora*), Unalaska mist-maid (*Romanzoffia unalaschensis*), and Queen Charlotte butterweed (*Senecio moresbiensis*). The field surveys concluded that no sensitive plant species were identified for the project area (Hasenjager, 2001).

3.12.3 Marine Mammals

Marine mammals currently listed in Alaska as threatened and endangered include one candidate species, the northern sea otter, seven species of endangered whales (northern, right, bowhead, sei, blue, fin, and humpback), and the Steller sea lion (endangered west of 144° and threatened east of 144° W longitude).

Of the threatened or endangered species in Alaska, the following three occur in the Hawk Inlet area:

- Steller sea lion (threatened east of 144° W longitude);
- Northern sea otter (Aleutian population - candidate species); and
- Humpback whale (all Humpbacks listed as endangered).

Steller Sea Lion (*Eumetopias jubatus*). Like harbor seals, Steller sea lions are common at Hawk Point where small groups frequently haul out. At least two haul-out sites occur within one mile of the Greens Creek delta. Fishermen, miners and research contractors have observed Steller sea lions hauled out on these rock piles just north of the entrance of Hawk Inlet, in Chatham Strait. These rocks are used by up to two dozen Steller sea lions at a time, on an intermittent basis. The Alaska Department of Fish and Game does not consider these sites as significant haulouts for Steller sea lions, and no critical habitat has been designated in the area (Ken Pitcher, 2002).

Adult Steller sea lion pursue a broad range of prey species, including Pacific cod, Pacific salmon, arrowtooth flounder, Pacific herring, Pacific sandlance, snailfish, rock greenling, cephalapods (squid and octopus), kelp greenling, and rocksole (NMFS 2001). All of these species are found in Hawk Inlet.

When the salmon are running in Greens Creek and Zinc Creek during summer months, Steller sea lions feed inside the Inlet. Though there is no formal documentation of herring in Hawk Inlet, it is highly probable that herring and eulachon occur in Hawk Inlet in the winter and the spring. To the extent that they do, it is also highly probable that Steller sea lions from the adjacent waters of Chatham Strait follow them into Hawk Inlet to feed (R.Carlson, NMFS Auke Bay Lab, pers. comm., 1998).

Humpback Whale (*Megaptera novaeangliae*). The humpback whale is most frequently sighted in Chatham Strait, where it is found feeding especially from mid-May until late September. Previous studies reported resident humpback populations for the June to September period ranged from approximately three to eight animals, increasing to as many as 20 during the October November migrations (Carlson, pers. comm., 1999).

Only occasionally have researchers sighted humpback whales inside the sill at the mouth of Hawk Inlet. Relative to other marine mammals, however, OIO (1996) reported that humpbacks are the most commonly observed cetaceans inside of Hawk Inlet, with a sighting frequency of approximately 80 percent. The sighting frequency compared to 7 percent for harbor porpoise, 5 percent for killer whale, 4 percent for minke whale, and 3 percent for Dall's porpoises (RTI, 1998).

Humpback whales feed extensively in Alaska during spring and summer months, storing reserves for fasting during breeding seasons at lower latitudes. In Southeast Alaska, humpback prey items include euphasiids and small schooling fish (herring, capelin, juvenile walleye pollock, and Pacific sandlance) (Mathews1996). Existing data indicates that all of these species, except capelin, occur in Hawk Inlet. Researchers observing humpback whales in Hawk Inlet postulated that whales may be pursuing patches of surface plankton or fish larvae that flow into the estuary.

Northern Sea Otter. Sea otters generally occupy "outside" waters of the Southeast Alaska panhandle, and are rarely seen inside, or east of Icy Strait. Two sightings have been confirmed within Chatham Strait in the past ten years. As the northern southeast population continues to grow, sea otters are seen further east in inside waters each year. Sea otters feed on sea urchins, young crab, and bivalves – all of these occur in Hawk Inlet. There are no confirmed reports of sea otters within Hawk Inlet, and it is unlikely they frequent or depend upon habitats within Hawk Inlet.

Professional staff operating the Greens Creek Mine have observed a few humpback whales in Hawk Inlet each year, and Steller sea lions transiting near the mouth and within Hawk Inlet every year. No northern sea otters have been confirmed inside Hawk Inlet (Oelklaus, 2002).

According to the Regional Administrator of the Alaska Region of the National Marine Fisheries Service (NMFS), although some of these species enter Hawk Inlet occasionally, none of them, nor any of their critical habitats, occurs at the location of the proposed action (J. Balsiger, 2001).

3.12.4 Salmon

Washington and Oregon Endangered Salmon. According to the 1997 Forest Plan, Pacific salmon from endangered species units (ESUs) originating in Washington and Oregon migrate through the Gulf of Alaska, and outside waters of Southeast Alaska. ESU's involve spawning habitat. Salmon from these ESUs are not known to occur within the project area (Forest Plan Vol. 1 pgs. J 1-13). Because these endangered salmon and the ESU's these endangered salmon stocks are found in are outside of the project area, they are not discussed further within this evaluation.

Island King Salmon. The only Alaska Region sensitive fish species in the project area is the island king salmon. The Forest Plan identifies Wheeler Creek, approximately three miles southwest of the Greens Creek Delta, as supporting a population of this species. Rearing juvenile king salmon also have been found in the middle and lower reaches of Greens Creek (Buell, 1992). During initial fish studies for the Greens Creek project, no king salmon juveniles were found in Greens, Zinc or Tributary creeks, and no ADF&G records indicated the presence of king salmon in creeks anywhere in or near Hawk Inlet, except for Wheeler Creek. Buell (2001) hypothesizes that the Greens Creek juveniles may have been the result of adults spawning there after straying from Wheeler Creek, or (less likely) from the small, Douglas Island Pink and Chum Hatchery (DIPAC), enhancement releases of kings. Although Greens Creek does not provide particularly good habitat for king salmon, Buell believes they have benefited from the Greens Creek Mine mitigation measure that opened spawning habitat above the falls.

Figure 3-27 Aerial mosaic of Lower Hawk Inlet, Admiralty Island. Stations shown S-1, S-2, S-4 and S-5 are sediment and worm sampling sites. Station S-3 is in the head of Hawk Inlet. Stations 1, 2, 3 and ESL are mussel sampling sites. Photo by R&M Engineering 1982

3.13 Marine and Aquatic Ecosystem

The affected marine and aquatic ecosystems in the project study area for this EIS include the marine waters of Hawk Inlet and the watersheds draining into the east side of Hawk Inlet (Figure 3-27.

Relevant findings from marine studies and long term monitoring efforts have been incorporated into this section. Detailed methods, results, and trends from these studies have been compiled in, "Technical Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations" (Ridgway, 2003). This document is in the planning record and has been furnished to NMFS.

Marine Biota and Habitats

The Hawk Inlet marine ecosystem is comprised of pelagic, demersal, benthic and intertidal communities. The major subtidal benthic (bottom) substrata that occur in Hawk Inlet are sands, muddy sands, muds, and rocks. Submerged sands primarily occur near the Greens Creek delta. This substratum contains large amounts of cobble and gravel; in areas where current velocities are high, sediments are frequently scoured to bedrock. Muddy-sand habitats occur primarily at the extreme northern end of Hawk Inlet. Submerged muddy-sand habitats also frequently contain relatively large amounts of cobble and gravel. Submerged muds occupy the central region of Hawk Inlet and contain large amounts of organic material. Submerged rocky habitats occur along the margins of the basin.

In general, in hard-bottom subtidal areas, anemones, snails, greensea urchins, starfish, sea cucumbers, sponges, bryzoans, and a wide variety of algae are dominant. King, Tanner, and Dungeness crabs, as well as a variety of edible shrimp, are also found in the hard bottom subtidal habitats. Those habitats in Hawk Inlet and Chatham Strait are typical in species composition and relative abundance to hard-bottom habitats of the region (Holland et al 1981).

Annelids (worms), mussels, clams, and small crustaceans dominate soft-bottom subtidal benthic habitats; annelids are generally the most abundant. The composition of subtidal soft-bottom habitats in Hawk Inlet depends upon physical properties of the sediments. These communities in Hawk Inlet contain more species than intertidal benthic communities and are similar to subtidal benthic communities reported to occur along Northeast Pacific coasts.

A summary of habitats and associated biota in Hawk Inlet and the adjoining portions of Chatham Strait is provided in Table 3-14.

Table 3-14 Features of major marine habitat types in Hawk Inlet, Admiralty Island (Source: Holland, et al. 1981)

Habitat Type	Area (ha)	No. of Species	Density Orgs/m^2	Dominant species	Location in Hawk Inlet
Protected (estuarine) intertidal muddy sands	226.4	36	49,480	Gastropods, bivalves, polychaetes	Head of Inlet
Protected subtidal muddy sands	147.3	41	7,596	Bivalves, polychaetes	Head of Inlet
Protected intertidal and subtidal muddy sands	48.8	52	13,776	Polychaetes, foramanifera, bivalves, copepods.	Pile Driver Cove
Unprotected intertidal sand	41.3	36	99,900	Foramanifera ns (sponges)	Greens Creek Delta
Intertidal and subtidal rocky	66.3	—	—	(samples from Chatham)	Shoreline and mouth of Inlet
Deep subtidal muds	321.8	52	14,061	Polychaetes, bivalves	Basin – Cannery
Submerged sill of sand-gravel-cobble	187.2	80	30,526	Polychaetes, gastropods, amphipods	Greens Creek Delta/002
Nereocystis kelp beds (sand)	125.4	69	67,352	Polychaetes, amphipods, bivalves	Interspersed
Transition areas	168.5	—	—	—	Interspersed

Marine Fish and Shellfish

Several commercial and non-commercial fish and shellfish species occur in this area — salmon, flathead sole, yellowfin and rock sole, arrowtooth and starry flounder, Pacific cod, white-, spotted and masked greenling, and shortfin eel pout. Halibut were also observed. Non-commercial species present included snake prickleback, sturgeon poacher, staghorn, great and spiny head sculpin, Pacific sandlance, daubed shanny, and copper rockfish. Schools of herring in spawning condition occur in the Inlet during spring (Carlson, pers. comm. 1999).

Shellfish species in Hawk Inlet include extensive clam beds, with little necks, cockles, soft-shell clam, horse clam and mussels. Tanner, Dungeness, king and hermit crabs are also abundant in shallow and deep Hawk Inlet habitats.

Federally managed fish and shellfish and their prey, as well as salmon in Hawk Inlet, are described under the Essential Fish Habitat below. The health of marine habitats and biota prior to operations and during the mine's production years to date is also discussed later in this section.

Hawk Inlet Area Fisheries

Sport fishing is discussed in the recreation section, and subsistence harvests of clams, crab and fish are described under the subsistence section. Pacific cod, sablefish, lingcod, and over a dozen species of rockfish are harvested annually in Hawk Inlet and in adjacent waters of Chatham Strait. All species of Pacific salmon, as well as Dungeness crab, brown crab, red king crab and bairdi Tanner crab are harvested inside Hawk Inlet and in Chatham Strait. The total volume of fish (except halibut), shellfish and salmon harvested in this vicinity was 9.3 million pounds in 2001.

Halibut harvests for Hawk Inlet are reported as part of a much larger region, and do not reflect the amount of fish taken from the project area. Historical information indicates that occasional commercial halibut fishing in the area yielded some large catches during 1914 to 1974, when the cannery was open. Since that time, smaller vessels fish individual fishing quotas near and occasionally inside of Hawk Inlet. Commercial fishing and tender vessels occasionally use Hawk Inlet as a mooring site.

3.14 Essential Fish Habitat and Habitat Areas of Particular Concern

Essential Fish Habitat (EFH) includes those waters and substrata necessary for fish spawning, breeding, rearing, and growth to maturity. In the context of EFH, "fish" refers to federally managed fish or shellfish species and their prey. EFH includes all segments of streams where salmon reside during any period of the year as well as the marine waters, substrates and biological communities of Hawk Inlet.

The National Marine Fisheries Service has identified Hawk Inlet as EFH for several marine and anadromous species. The NMFS queriable EFH database (www.fakr.noaa.gov\efh) and all other sources of data, including dive surveys, commercial and sport fishing data, and research data were used to develop the following list of species having EFH in Hawk Inlet. In addition to federally managed groundfish and shellfish, species listed in Hawk Inlet include major prey species, such as forage fish and shrimp (Miller, 2003).

Table 3-15 FMP Managed Species with EFH in Hawk Inlet, Admiralty Island and adjacent watersheds.

Federally Managed Species		
Common Name	**Scientific Name**	**Life History Stage**
Walleye pollock	*Theragra chalcogramma*	eggs,juveniles,mature
Flathead sole	*Hippoglossoides elassodon*	Not specified
Yellowfin sole	*Limanda aspera*	Not specified
Arrowtooth flounder	*Atheresthes stomias*	Not specified
Sablefish	*Anoploploma fimbria*	Not specified
Pacific ocean perch	*Sebastes alutus*	Not specified
Rock sole	*Lepidopsetta bilineatus*	Not specified
Pacific cod	*Gadus macrocephalus*	Not specified
Sculpins (9 species)	Family Cottidae	Not specified
Pacific salmon	*Onchorynchus* sp.	Egg, juvenile, adult
Pink salmon	*O. gorbuscha*	Egg, juvenile, adult
Chum salmon	*O. keta*	Egg, juvenile, adult
Coho salmon	*O. kisutch*	Egg, juvenile, adult
Forage Fish Complex		
Eulachon	*Thaleichthys pacificus*	Not specified
Rainbow smelt	*Osmerus mordax*	Not specified
Pacific herring	*Clupea harengus*	Not specified
Shrimp	*Pandalidae, Crangonidae*	Not specified
Squid	*Loligo*	Not specified
Octopus	*O.dofleini/rubescens*	Not specified
Red king crab	*Paralithodes camtchatica*	Not specified
Snow crab	*Chionocetes opilio*	Not specified
Tanner crab	*Chionocetes tanneri*	Not specified

Anadromous Waters

Although all five species of Pacific salmon are found in Hawk Inlet, it is considered EFH for pink, chum and coho. General descriptions of the aquatic environments of these systems were given in the Greens Creek FEIS (USDA FS, 1983), along with descriptions of Cannery Creek, Piledriver Creek, and several unnamed creeks that enter the head of Hawk Inlet. These streams are part of EFH in the area. Recent studies (ADF&G 2003) indicate that Greens Creek and Tributary Creek have complex, diverse aquatic communities and

high population levels of freshwater algae (periphyton), insects and other aquatic invertebrates.

Detailed descriptions of these systems, along with a summary of changes since the 1983 EIS are contained in the above referenced Ridgway, 2003 (See Figure 3-9).

Salmon spawning in any of these streams and juveniles emerging from streams will migrate through Hawk Inlet which has the potential to be affected. Adult salmon stage in the lower portion of the inlet before migrating upstream in Greens and Zinc Creeks to spawn. Juvenile fish moving from the creeks to the sea can accumulate in shallow waters in most parts of the Inlet where brackish surface waters predominate prior to migrating out to sea.

Table 3-16 Fish Species Found in Streams in or near the Greens Creek Mine Project Area

Creek	Juveniles / Resident Adults						Anadromous Adults			
	Coho	Cutthroat Trout	Dolly Varden	Sockeye	Sculpin	Stickleback	Pink	Chum	Dolly Varden	Coho
Greens Creek	++	+	++	0	++	+	++	++	+	+
Zinc Creek	++	+	++	0	++	+	++	++	+	+
Tributary Creek	+	+	+	0	++	0	++	0	+	+
Young Bay Trib.	++	++	+	+	++	++	0	0	?	+
Fowler Creek	++	+	++	0	++	+	++	+	++	+
Lower Fowler Trib.	++	+	++	0	?	0	0	0	?	+
Upper Fowler Trib.	0	0	0	0	0	0	0	0	0	+
Lower G.C. Trib.	0	0	0	0	0	0	0	0	0	0
Piledriver Creek	++	0	+	0	++	+	+	+	+	0
Piledriver Cr. Trib.	++	0	+	0	?	0	0	?	?	+
Upper Hawk Tribs.	+	?	+	0	++	++	+	?	?	?
Pristine Pond	0	0	0	0	0	0	0	0	0	0
Cannery Creek	0	?	?	0	0	0	0	0	0	0

Abundance indicators: ++ = abundant; + = moderate occurrence or few; 0 = not found; ? = presence strongly suspected but not confirmed. Observations were made in the early 1980's

Habitat Areas of Particular Concern (HAPC)

Habitat areas of particular concern (HAPC) are subsets of EFH that may be rare, sensitive, or particularly vulnerable to human impacts. HAPCs in Alaska include eelgrass, kelp and mussel beds (NMFS, 2002). Approximately 125 hectares of bull kelp habitat lie between Hawk Point and the head of Hawk Inlet (Holland et al. 1981). Limited surveys revealed that Hawk Inlet kelp beds support about 70 species of invertebrates in very high densities. Adult and juvenile salmon use these kelp beds as protection during migration and juvenile feeding.

3.15 Status of Marine and Aquatic Habitats in Hawk Inlet

Physical Conditions in Hawk Inlet

A fish cannery at the current site of the Greens Creek ore loading facility burned in 1974, dropping most of the building contents onto the underlying ocean floor. When preparing the site for the future ship loading facilities, much of this material was recovered from the area, but considerable debris, including large quantities of metal, remain on the seafloor.

Physical changes to the marine environment resulting from the mining operation include minor alterations of the seafloor for installation of outfall pipes and diffusers at 001 and 002, piling driven for modifications to the dock and loading facility, and impacts of the ore concentrate spill on the seafloor near the dock. Vessels traveling to and from the facility may have led to disturbances to fish and wildlife, but these are considered temporary and have no effect on populations. No major fuel spills on land or water have been reported which would suggest petroleum hydrocarbon impacts to Hawk Inlet.

Metals in Hawk Inlet

In anticipation of the Greens Creek Mine development, government agency scientists and biological consultants carried out surveys of marine life and baseline studies of heavy metals in the environment starting in 1981. In order to better understand the results of these data and all subsequent heavy metal concentration data in this section, national environmental standards guidelines for metals concentrations were used for comparison with Hawk Inlet data.

Pre-Mining Operations Sediment Metals average levels show some consistency across stations, but the standard deviations for these data indicate high variability, typical of natural conditions. These data are useful as baseline values against which to compare metal values after mining began. Only a subset of these data (Stations S-1, S-2, & S-3) were used to calculate

baseline values because not all stations or samples represent natural conditions for comparison.

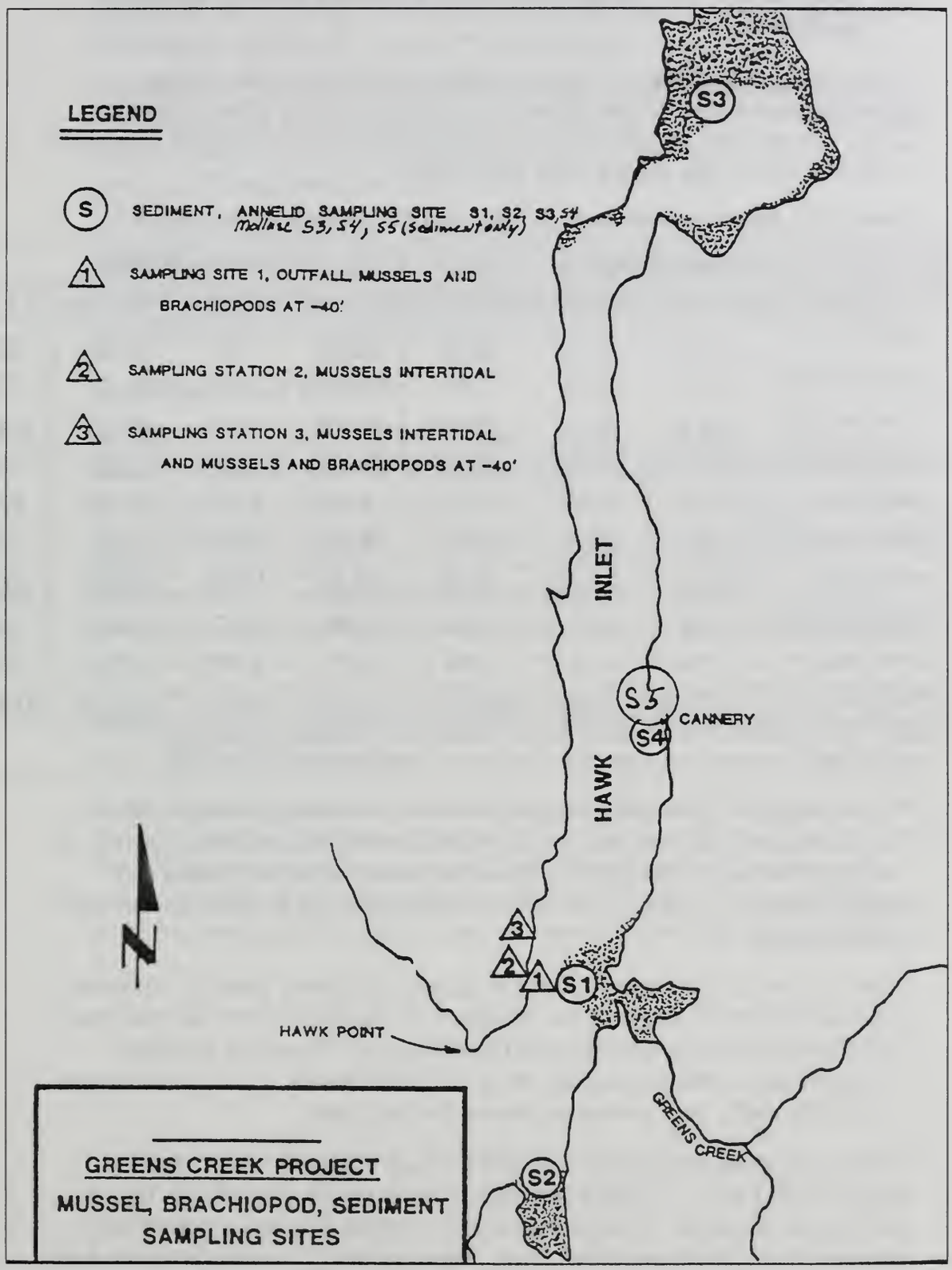
Stations S-4 and S-5 have been influenced by both the old cannery operation and mine exploration work prior to opening of the mine, and therefore are not considered suitable as a pre-mining background stations.

In comparing all Hawk Inlet metals to National Status and Trends (NST) levels, it appears that several metals are greater than the NST (Effects Range Low (ERLs). The average chromium and nickel values exceed ERL levels at every site in Hawk Inlet. Arsenic and copper are slightly above ERL levels at Station S-3 and Arsenic, Chromium, Lead and Nickel are all above ERL at Station S-4, near the old cannery site. None of the pre-mining metals levels exceeded (Effects Range Median) ERM or (Apparent Effects Threshold) AET levels.

Polychaete worms – Pre-mining polychaete worm (*Nephthys*) tissue concentrations indicate that only copper appears to be slightly elevated at station ESL, over the other sites S-1, S-2, and S-3.

Mussels – Mussel tissue data indicated that cadmium and zinc at most stations are elevated above Alaskan mussel watch average levels, and mercury is slightly higher than Mussel Watch levels at station S-1.

Figure 3-28 Hawk Inlet Sediment and Biota Sample Site Map



Comparison of Pre-Mining and Production Period Metals in Sediments

A summary comparing pre-mining baseline metal levels with mining production period levels for stations S-1, S-2 and S-3 are shown in Table 3-17. The average mining period values for station S-1, the outfall monitoring intertidal station, are shown in the last column.

Table 3-17 Metals in Sediment: Average and Range Stations S-1, S-2, S-3

	Pre-Mining Baseline:			Mining Period:			
Metal	Average	Minimum	Maximum	Average	Minimum	Maximum	S-1 Avg
Arsenic (As)	10.57	3.30	33.50	**11.40**	1.26	33.50	8.77
Cadmium (Cd)	0.43	0.03	1.09	0.41	0.03	1.53	0.29
Chromium (Cr)	125.22	56.00	188.00	85.46	12.50	450.00	114.05
Copper (Cu)	26.73	11.90	55.20	23.99	7.80	55.20	19.98
Lead (Pb)	7.95	2.30	15.10	9.49	1.48	26.00	**9.78**
Mercury (Hg)	0.05	0.01	0.12	**0.06**	0.00	0.16	**0.06**
Nickel (Ni)	46.91	27.40	75.80	40.49	13.00	86.90	**52.45**
Selenium (Se)	1.19	0.17	3.50	**2.08**	0.17	14.00	**2.36**
Silver (Ag)	0.13	0.01	0.49	0.15	0.01	0.59	**0.14**
Zinc (Zn)	111.75	52.80	200.00	104.22	30.50	200.00	**113.45**

BOLD Mining production period values that are higher than the average baseline level.
UNDERLINED Any value that exceeds NST ERL levels, note there is no ERL for Se.

This comparison shows that across all stations, the average metal levels for As, Pb, Hg, and Ag have only slightly increased during the mining period. Se roughly doubled in concentration at all stations between pre-mining and mining periods. Cd, Cr, Cu, Ni, and Zn have decreased at these stations since mining began.

Based on the data (Ridgway, 2003), it appears that heavy metals in sediment near the outfall 002 site have not increased substantially above the area-wide baseline levels during mining years (baseline is S1, S2 and S3 average). Although some metals remained above NST ERL levels, these metals appear to be of naturally high concentrations in the study area.

When comparing pre-mining sediment levels at station S-1 to production period mining at S-1, marked increases in some metals (As, Cd, Pb, Hg, Se and Ag) are apparent. Measurements at S-1 during the mining period have exceeded ERL levels numerous times, however, only Ni and Cr have reached ERM levels. Based on National Status and Trends interpretations some

elevated metal levels in sediments at the outfall site subsequent to mining operations, are at levels warranting concern, and may be toxic to marine life (for example amphipods, marine worms, and bivalves).

Relative to NST levels, As, Cr, and Ni average levels are consistently higher than ERL – both prior to and subsequent to mining activity. Maximum levels detected during the mining period exceeded ERL for As, Cd, Cr, Cu, Hg, Ni, and Zn. All metal levels are well-below NST ERM levels.

The USFWS independently sampled sediment throughout Hawk Inlet in 1997 (USDOI, 1993; Rudis 2001). In general, the area wide averages they reported from 10 sites were comparable for mining period metals, except Cd levels reported by USFWS were substantially higher than mining period averages.

Stations S-4 and S-5

In 1989, the first attempt to load a barge with ore concentrate resulted in a spill of concentrate into Hawk Inlet. A suction dredge company was brought on site during the summer of 1995. This effort was confounded somewhat by the residual debris from the 1974 cannery facility fire. About twice as much material was dredged from the site as was predicted by earlier dive assessments of the spill quantity. The KGCMC contractor added another monitoring site to the shiploader area (Site 5 South, 5 North is a continuation of the original Site 5). The two Site 5 areas now bracket the concentrate spill area. S-4 is an intertidal site. Following the 1989 ore concentrate spill, metals concentrations in sediments near the ore loading dock increased abruptly and have varied widely since then.

Compared to the National Status and Trends data and AET levels, some heavy metals in marine sediments at stations S-4, S-5S and S-4N are present at levels that are likely toxic to bivalves, amphipods, and the infaunal community (organisms burrowed in the seafloor). Cd, Cu, Pb, Hg, Se, Ag, and Zn occur at the ore loading dock sites at levels of concern for biological communities.

Table 3-18 Metal Concentrations in Sediments at Stations S-4 and S-5.

Metal	Baseline Average	Mining Average	Mining S-4	Mining S-5S	Mining S-5N
Arsenic	10.57	11.40	**10.83**	**10.43**	***19.60***
Cadmium	0.43	0.41	***1.22***	***3.77***	***18.75**** [1]
Chromium	125.22	85.46	77.24[1]	32.48	80.77[1]
Copper	26.73	23.99	**71.58**	***79.91***	***290.40****
Lead	7.95	9.49	***171.19***	***282.24****	***1525.55**** [2]
Mercury	0.05	0.06	***0.28***	***0.51***	***3.04****
Nickel	46.91	40.49	30.81	36.60	37.73
Selenium	1.19 [3]	2.08 [3]	***1.48*** [3]	**1.81** [3]	***2.23*** [3]
Silver	0.13	0.15	***1.12***	***1.80***	***3.07**** [3]
Zinc	111.75	104.22	***246.80***	***694.94**** [4]	***2867.48**** [4]

BOLD figures are higher than the baseline average. ***BOLD ITALICIZED*** values are higher than the Mining period average. UNDERLINED values exceed NST ERLs, *values exceed NST ERMs, and noted values exceed Apparent Effects Threshold (AET) for identified species groups: 1. *Neanthes* bioassays 2. Bivalves 3. Amphipods 4. Infaunal community impacts

Polychaete Worms

Metal concentrations in the marine worms, *Nephthys*, increased for Cr, Pb and Ni. All maximum values for stations S1, S2, and S3 exceeded the baseline levels. This suggests that the elevated concentrations in this worm species are related to mining activities.

Some metals at station S-4 were higher than baseline average values, As, Cr, Cu, Pb, Ni, and Ag. Of these, As, Cr, and Ni are slightly higher than the baseline or production period levels. Remaining metals at S-4 are higher than postmining baseline average values by varying degrees: Pb(24X) and Ag (5X). It is not known whether these levels are toxic to worms, nor whether the metals in worm tissue are biologically available to species that prey on these worms.

Mussels

Both the USFWS and the Oceanographic Institute of Oregon (OIO) have monitored levels of metals in mussels. The USFWS study showed that average levels for Cu, Pb, and Zn were higher in 1997 than in 1987 at 10 stations in Hawk Inlet, (Rudis 2001). OIO results show that average levels for four metals also increased: Cr (2x), Pb (2.3X), Ni (1.7X), and Se (1.1X). Whereas maximum measurements (spikes) for all metals except As, Hg, and

Ag exceeded Alaskan Mussel Watch average levels, the average mining production period metal levels are generally below Mussel Watch averages for Alaska.

The exception to this is Cd, which was above Mussel Watch Alaska averages prior to and subsequent to mining operations. Because the USFWS Hawk Inlet-wide levels of Pb increased similarly to the outfall monitoring site levels of Pb, these increases over time may be due to natural increases in Pb in the environment. Overall, these data suggest that mussels show elevated levels of Cd, Pb, Se, and Zn during the mining activity time period.

Current Status of Hawk Inlet Marine Ecosystem

The status of the health of marine and aquatic can be viewed based on the number of types of creatures present in an area (species diversity, or "biodiversity"), the number of individual creatures in an area (species abundance), and quality of the environment (habitat integrity relative to pristine conditions).

For the marine environment, there are no data available to numerically compare diversity or abundance of organisms between pre-mining and post-mining years. Observations by fishermen and researchers suggests that the physical features and biotic communities of Hawk Inlet remain intact following nearly 12 years of operation of the mine and is similar to adjacent inlets.

Marine species which consume sedentary seafloor organisms such as worms and bivalves would be most susceptible to trophic transfer of some metals. Based on the suite of species listed as having Essential Fish Habitat in Hawk Inlet, the species most likely to encounter these elevated metal levels through their diet and habitat uses would include the flatfishes (*e.g.* yellowfin sole, arrowtooth flounder, flathead sole, and rock sole), pacific cod, sculpin and crab species. Pacific halibut also have similar consumption patterns to these species. All of these species consume worms, bivalves, and crab.

Other migratory and resident fish, mammals, and birds which consume seafloor-dwelling organisms near the ore loading dock would also likely encounter elevated metal levels in their diet. There are no data available to evaluate whether metals are increasing through trophic transfer, or biomagnification at higher trophic levels in Hawk Inlet marine species such as fish, crab and mammals.

3.16 Heritage Resources

The evaluation of the heritage resources of the affected environment and potential impacts was made based on an archaeological impact assessment (Carlson, 1991) carried out prior to development of an Environmental Assessment (USDAFS, 1992) of the mining operation, supplemented by information developed previously by Harritt (referenced as NPS, 1998).

Available data indicate that humans have been present in the Southeast Alaska archipelago and mainland areas for at least 10,000 years. The Wooshkeetaan clan of the Auk among others historically used the Hawk Inlet area. Given the length of time humans have lived in Southeast Alaska, the geomorphology of the area, and the presence of anadromous streams and other faunal resources, there is potential in the area for the discovery of pre-Holocene era heritage resources that would contribute to knowledge of the arrival of early man in the New World.

Two midden sites and four sites dating to the historic era are located within the general project area. The midden sites were initially recorded by Carlson (1981) and subsequent investigation was conducted by Davis (1990). Remains at the Greens Creek site have been radiocarbon dated from around the beginning of the first millennium AD (AD 5) to approximately AD 735. Although the site on Young Bay has been radiocarbon dated from approximately 890 BC to AD 1810, the latter date is regarded as too recent, and not a reflection of the true age of the occupation (op cit).

Four of these documented sites have been evaluated for significance, while two of the historic sites are located well outside the area of potential effect. Greens Creek Midden site (JUN-090) and the Jacobsen Cabin (JUN-236) have been determined to be ineligible for inclusion on the National Register of Historic Places while the Hawk Inlet Cannery site (JUN-092) and Young Bay Midden site have been determined to be eligible for inclusion on the National Register of Historic Places.

In compliance with Section 106 of the National Historic Preservation Act (NHPA), the Forest Service has identified historic properties that might be affected, assessed effects to those properties, and offered to consult with the Tribes, Native Corporations and other interested parties in the area.

3.17 Subsistence

Section 810 of the Alaska National Interest Lands Conservation Act (ANILCA) requires that all activities proposed on Federal lands be evaluated to determine if they would significantly restrict subsistence uses or

opportunities. This determination is made in Section 4.13 of this document for each of the alternatives.

Section 803 of ANILCA defines subsistence as follows:

"The customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumptions as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of the nonedible byproducts of fish and wildlife resources taken for personal or family consumption; for barter, or sharing for personal or family consumption; and for customary trade."

Rural subsistence communities near the Hawk Inlet project area are Angoon, 44 miles to the south, Tenakee Springs, 28 miles to the southwest, Hoonah, 28 miles to the west, and Funter Bay, 10 miles to the north. Juneau is a non-rural community located 18 miles to the east.

Wild foods are important nutritionally and culturally to residents in these communities (Krause 1970, DeLaguna 1960, Goldschmidt and Haas 1946, Leghorn and Kookesh 1987, George and Bosworth 1988, and Schroeder and Kookesh 1990, Emmons 1991). Deer, salmon, halibut, shellfish, seal, waterfowl, plants, and berries are important subsistence foods.

Hawk Inlet is not in a Customary and Traditional Use Area for any rural community (50 CFR Part 100 and 36 CFR Part 242). However, the Hawk Inlet area has long been used for subsistence hunting, fishing, and gathering. Hawk Inlet is also a safe harbor for subsistence users boating along the remote and exposed northwest shore of Admiralty Island. Zink, Greens, Tributary, and Wheeler Creek support anadromous salmon runs and the coastal beach fringes, grass meadows, and adjacent forest support deer, waterfowl, and plant/berry resources.

Goldschmidt and Haas (1946, 1998) documented the use and occupancy of the Tlingit and Haida Indians in 12 native communities in Southeast Alaska. They reported that in 1946 that Hawk Inlet was in the "aboriginal use and ownership" area of Auk Tlingits from the Juneau-Douglas Territory. They reported that the Angoon people used the western shore of Admiralty Island south of Point Marsden, a point at the south entrance to Hawk Inlet, and that the Hoonah territory ended at the east end of Icy Strait some 8 miles west of Hawk Inlet. The boundaries on their territorial maps were based on their efforts to interview knowledgeable people in each community but they caution that not all of the best informants were likely interviewed and that these territories changed over time.

Subsistence use patterns for residents of Angoon, Hoonah, Tenakee Springs, and other communities in Southeast Alaska have been studied by ADF&G.

George and Bosworth (1988) reported on the subsistence activities of Angoon residents based on household surveys conducted in 1985. They reported that Hawk Inlet was a deer hunting and shellfish harvesting area for Angoon residents.

Schroeder and Kookesh (1990) reported on the subsistence activities of Hoonah residents based on household surveys and interviews with Hoonah elders conducted in 1986 and 1987. They report that the Hawk Inlet area is in the area used by Hoonah residents for subsistence harvest of deer, salmon, and marine fish, invertebrates, and mammals.

Leghorn and Kookesh (1987) did not report any subsistence use of the Hawk Inlet area by residents of Tenakee Springs. Subsistence surveys have not been completed for the Juneau area by the State of Alaska, because Juneau is not designated as a "rural" area.

3.18 Recreation

Recreational use occurs in Hawk Inlet and the surrounding area, but is not allowed in the project area itself on land owned or leased by Greens Creek due to potential conflicts with heavy equipment and mining operations. Alaska Public Survey (APS) results indicate that Juneau residents are predominant users of the Hawk Inlet area for recreation. The other population centers nearest to the project area are Hoonah, and Angoon and it is probable, but not documented, that there is also some recreational use of the area by residents of those communities. Dominant recreation activities in the Greens Creek project vicinity are hunting, trapping, and saltwater fishing. Juneau fly-fishing guides take clients to the delta of Greens Creek where it empties into Hawk Inlet approximately one mile south of the tailings pile. Trapping occurs primarily along the shores of Hawk Inlet. Tourism is not a factor in the study area.

Hawk Inlet receives its largest recreational use during the deer-hunting season. In the summer months the inlet provides a protected moorage for sailboats, cabin cruisers, and commercial fishing boats. Hawk Inlet and Young Bay beaches also provide suitable landing space for wheeled aircraft. Such landings are permitted by the State, which owns the land below mean high tide. Young Bay recreational use is generally related to day trip activities, while Hawk Inlet is used for overnight trips. Recreational users access Hawk Inlet by boat and float plane. There is no regular public transportation service to the area.

Some of the recreational activity in Hawk Inlet is related to cabins in the inlet and at Wheeler Creek. These users/owners use the area for various activities, averaging 110 to 150 user days per year. Comments from owners/users

indicate there may be as many people using Hawk Inlet without cabin access, as there are users who stay in cabins.

In the 2001 – 2002 hunting season (August – January), 239 deer hunters hunted 593 days in Hawk Inlet and Young Bay drainages. One hundred and thirty-three hunters were successful, taking a total of 145 bucks and 114 does (ADF&G 2001 Deer Hunter Survey Summary Statistics). ADF&G statistics do not differentiate between Young Bay and Hawk Inlet drainages, but it is probable that the majority of the hunting occurred on the Young Bay side because of its much easier access by Juneau residents.

Table 3-19 Brown Bear Shot

Year	Sex	* Type	Res/ Nonres
1963	M	8	R
1965	3 M	8	R
1967	2 M	8	R
1969	M	8	R
1970	2 F	8	R
1972	M	8	R
1972	3 F / 5 M	8	R
1973	3 M	8	R
1974	F	8	R
1975	1 F / 1 M	8	N
1976	2 M	8	1 R / 1N
1978	M	8	R
1981	M	8	N
1983	1 F / 1 M	8	1 R / N
1984	1 F / 1 M	1 8 / 1 5	R
1986	3 M	8	2 R / 1 N
1988	1 F / 1 M	1 1 / 1 8	R
1989	M	8	N
1990	2 F / 2 M	8	R
1991	3 F / 3 M	8	R
1992	2 F / 1 M	1 2 / 2 8	R
1993	M	1	
1994	1 F / 2 M	8	2 R / 1 N
1995	2 M	8	R
1997	2 F / 1 M	8	1 R / 2 N
1998	3 M	8	1 R / 2 N
1999	3 M	8	1 R / 2 N
2000	1 F / 5 M	8	1 R / 4 N

*TYPE: 8-sport harvest, 5-illegal harvest, 1-defense of life or property, 2-found dead
*RES: R=Resident, N=Non Resident

(ADF&G 2002)

ADF&G data on the numbers of brown bears shot by sport hunters in the Hawk Inlet area show an average of 1.8 bears per year taken in the Hawk Inlet area from 1963 through 2000.

The ADF&G believes a few people hunt ducks in Hawk Inlet during mid-October. These people use cabin cruiser type vessels to reach Hawk Inlet and generally stay for several days.

The furbearers trapped in the area are mink, marten, and river otter. There are no records available that indicate levels of trapping activity or harvests of mink. Annual ADF&G records show that marten and otter harvest occurs sporadically in Hawk Inlet with large harvests of marten in 1984 and 1997 (Table 3-20 and Table 3-21).

Table 3-20 Hawk Inlet Documented I Otter Harvest

Year	Number
1981	6
1984	7
1985	1
1991	8
1994	4
1997	7

ADF&G 2002

Table 3-21 Hawk Inlet Documented Marten Harvest

Year	Number
1984	14
1988	1
1991	5
1992	2
1996	7
1997	22
2000	2
2001	1

3.19 Socioeconomic

To the extent that tailings disposal alternatives either extend or reduce the life of the Greens Creek Mine, Juneau could experience socioeconomic impacts. Local employment and income, population, school enrollment, housing, and local government revenues would be affected. Baseline data are presented below.

3.19.1 Employment and Income

The Juneau City and Borough employment base included 16,660 non-agricultural wage and salary (NAWS) jobs in 1999. Not included in this total are self-employed people (including commercial fishermen) and uniformed military personnel. The NAWS payroll totaled $538 million in Juneau in 1999.

Compared to 1998, NAWS employment in Juneau increased by 200 jobs in 1999, a 1.2 percent growth rate. Since 1990, Juneau area employment has been growing at an average annual rate of about 1.7 percent.

The government sector continues to dominate the Juneau economy, accounting for 41 percent of all jobs and 52 percent of all payroll in 1999. This includes state, federal and local government jobs. State government alone directly accounts for one-quarter of the NAWS jobs in Juneau and 30 percent of payroll.

State government is by far Juneau's most important basic industry. In terms of employment, tourism ranks second among Juneau's basic industries (with an annual average of approximately 1,600 jobs), followed by the federal government.

According to Bureau of Economic Analysis data, total personal income for Juneau residents reached $1.01 billion in 1998. Per capita personal income averaged $33,516 in 1998.

Table 3-22 Non-Agriculture Wage and Salary Employment and Earnings, City and Borough of Juneau, 1999

Industrial Classification	Annual Average Employment	Annual Earnings ($)	Average Monthly Earnings ($)
Total Industries	16,660	$537,587,335	$ 2,689
Private Ownership	9,755	260,079,405	2,222
Total Government	6,905	277,507,930	3,349
Agriculture, Forestry & Fishing	100	2,532,241	2,121
Mining	295	Nondisclosable	Nondisclosable
Metal mining	277	Nondisclosable	Nondisclosable
Nonmetallic minerals ex fuels	18	702,603	3,283
Construction	720	29,226,859	3,384
Manufacturing	357	12,629,414	2,945
Durable Goods	115	6,271,224	4,544
Non-Durable Goods	242	6,358,190	2,186
Trans., Comm. & Utilities	1,171	39,433,519	2,807
Total Trade	2,863	57,808,123	1,682
Wholesale Trade	342	10,200,920	2,487
Retail Trade	2,522	47,607,203	1,573
Finance, Ins. & Real Estate	519	18,757,685	3,014
Services	3,722	78,286,262	1,753
Non-Classified	8	217,621	2,244
Federal Government	865	46,614,442	4,491
State Government	4,271	165,529,935	3,230
Local Government	1,769	65,363,553	3,079

Source: Alaska Department of Labor & Workforce Development, Research and Analysis Section.

Table 3-23 Non-Agriculture Wage and Salary Employment, City and Borough of Juneau, 1990 to 1999

	1990**	1991	1992	1993	1994***	1995	1996	1997	1998	1999
Total Industries	14,122	14,081	14,518	14,612	15,336	15,812	16,165	16,518	16,461	16,660
Mining	75	84	75	75	160	187	257	302	313	295
Construction	414	518	548	717	636	629	702	734	685	720
Manufacturing	148	199	268	270	287	327	364	383	375	357
Transportation	911	880	957	909	989	1,072	1,070	1,199	1,245	1,171
Trade	2,239	2,416	2,464	2,552	2,775	2,920	2,941	2,912	2,824	2,863
Wholesale Trade	197	217	197	198	197	184	226	275	306	342
Retail Trade	2,042	2,199	2,267	2,353	2,578	2,736	2,715	2,637	2,518	2,522
Finance	496	558	585	618	703	681	695	740	676	519
Services & Misc.	2,333	2,279	2,357	2,449	2,824	3,017	3,134	3,335	3,439	3,722
Ag, Forest, & Fish	*	*	70	70	74	78	80	98	92	100
Nonclassifiable	*	*	2	13	11	7	8	5	18	8
Government	7,449	7,078	7,191	6,940	6,877	6,893	6,915	6,810	6,793	6,905
Federal	1,406	1,039	1,094	961	937	908	894	868	847	865
State	4,535	4,518	4,530	4,373	4,301	4,315	4,318	4,232	4,237	4,271
Local	1,508	1,521	1,567	1,606	1,640	1,671	1,703	1,710	1,709	1,769

* Nondisclosable

** 1990 Federal government employment overreported. All 1990 Census workers statewide reported in Juneau. Actual federal employment is 350-400 less than indicated.

*** Juneau annexed Green's Creek Mine effective 1-1-94. Mining industry employment for 1994 includes Green's Creek but prior years do not.

Source: Alaska Department of Labor & Workforce Development, Research and Analysis Section.

Over the past decade, the composition of Juneau's employment has changed. Nearly all of Juneau's growth during the last decade has been in trade, service, and transportation—sectors most affected by the visitor industry. During that period, Juneau gained nearly 3,100 private-sector jobs, while the government-sector lost 500 jobs. In 1990, government directly accounted for 53 percent of all local jobs (including federal, state, and local government positions). Today government accounts for 42 percent of all jobs in Juneau. Government decline includes 500 federal jobs and 250 state jobs. Local government increased by 260 jobs.

Juneau has also seen a steady decline in real wages (inflation adjusted). Average real annual salaries have declined by 10 percent since 1990, from $36,000 to $32,000 a year. Government real wages have slipped from $46,000 in 1990 to $40,000 today, a 13 percent decline. During the same period, state wages fell 20 percent, from $47,000 to $39,000 today. Private-sector average wages increased 2 percent, from $26,000 to $26,600.

3.19.2 Population

According to the 2000 Census, Juneau's population in the year 2000 was 30,711. Between 1990 and 1999, the population of the City and Borough of Juneau (CBJ) has increased at an average annual rate of 1.3 percent. Population growth has generally paralleled statewide increases over the same time period.

Table 3-24 City and Borough of Juneau Population, 1990-2000

Year	Population	Rate of Change
1990	26,751	
1991	27,579	3 percent
1992	28,253	2
1993	28,448	<1
1994	28,454	<1
1995	28,700	<1
1996	29,230	2
1997	29,713	2
1998	30,021	1
1999	30,189	<1
2000	30,711	na*

*Because of different counting methodologies, the increase in population between 1999 and 2000 reported here may not reflect actual population growth.

Source: Alaska Department of Labor & Workforce Development, Research and Analysis Section (1991 through 1999), and US Bureau of the Census (1990 and 2000).

The Juneau population is projected to continue to increase gradually over the next 20 years, according to the Alaska Department of Labor and Workforce

Development. Based upon that agency's projected long-term growth rates of 0.5 percent to 1.3 percent, Juneau's population could grow to between 33,900 and 39,800 over the next 20 years.

3.19.3 School Enrollment

As of April 27, 2001, Juneau's public school enrollment (grades K-12) totaled 5,430 students. School enrollment has declined in each of the last two school years after peaking at 5,588 students in 1998-99. Since then, the Juneau school district has lost a total of 158 students, a 2.8 percent decline.

Table 3-25 City and Borough of Juneau, Public School Enrollment, K-12

Year	Population	Rate of Change
1994-95	5,315	–
1995-96	5,447	2.5 percent
1996-97	5,529	1.5 percent
1997-98	5,530	0.0 percent
1998-99	5,588	1.0 percent
1999-00	5,496	-1.6 percent
2000-01	5,430	-1.2 percent

Enrollment is as of the end of each school year, except 2000-01, which is as of April 27.

Source: City and Borough of Juneau School District.

3.19.4 Housing

Housing construction has slowed in recent years. In 2000, 108 new housing construction permits were issued, marking the fifth consecutive annual decline in housing construction, and the lowest level since 1993. Juneau's housing inventory now totals approximately 11,000 units, with a vacancy rate of about 4 percent, according to the most recent CBJ data.

Table 3-26 City and Borough of Juneau, New Housing Units and Vacancy Rate, 1990-2000

Year	Number of New Dwelling Units	Vacancy Rate
1990	72	1.5
1991	97	1.2
1992	120	1.2
1993	102	0.9
1994	252	0.8
1995	370	1.0
1996	349	2.0
1997	232	2.7
1998	147	3.6
1999	138	Na
2000	108	Na

Source: City and Borough of Juneau, Department of Community Development

3.19.5 Local Government Revenue

Over three-quarters of CBJ's revenues (78 percent) come from local sources, such as user fees and permits, property tax, and sales tax. The state provides 19 percent of total revenue, while federal sources account for 3 percent of revenue.

Table 3-27 City and Borough of Juneau Operating Revenues, FY2000 Actual

Source	Revenue	Percent Total Revenue
State Support	$29,839,200	19.3 percent
Federal Support	4,198,800	2.7
Local Support	120,557,400	78.0
Property Tax	25,570,500	16.5
Sales Tax	27,799,200	17.9
Alcohol Tax	566,600	<1.0
Tobacco Excise Tax	269,400	<1.0
Hotel Tax	1,009,400	<1.0
User Fees & Permits	55,709,900	36.0
Penalties & Fines	1,310,000	<1.0
Other	8,322,400	5.4
Total Revenues	**$154,595,400**	**100**

Source: City and Borough of Juneau

Chapter 4
Environmental Consequences

4 Environmental Consequences

4.1 Introduction

This chapter presents the results of the analyses of potential impacts to the affected environment from the four alternatives. This chapter consolidates the discussions of environmental consequences and sets forth:

- The results of the analyses of potential impacts from the four alternatives on the resources discussed in Chapter 3,
- Any adverse environmental effects which cannot be avoided should an alternative be implemented,
- The relationship between short-term uses of the human environment and the maintenance and enhancement of long-term productivity, and
- Any irreversible or irretrievable commitments of resources which would be involved in an alternative proposal should it be implemented.

The scope and level of detail devoted to the impact analysis for each resource is a function of the concerns that were identified during scoping Sand those carried forward as significant issues.

Each of the alternatives has been described in detail in Chapter 2, but they can be summarized as follows.

- **Alternative A -** The "No Action" alternative would not modify the existing general plan of operations to permit any expansion of the tailings disposal facility. Under the current permit the existing tailings facility has space for about 1 million tons of tailings, or roughly 2 years of tailings disposal at the current level of production. KGCMC would continue its present method of generating whole tailings. The tailings would be placed without chemical or biological additives other than those currently allowed by the State of Alaska solid waste permit. The footprint of the tailings pile would be limited to 29 acres in size, and would utilize the post-closure construction of an engineered soil cover on the pile to minimize the transmission of oxygen and water into the pile.
- **Alternative B -** The Proposed Action alternative would modify the general plan of operations to permit an increase in the size of the tailings disposal facility. KGCMC would continue its present method of generating whole tailings. The tailings would be placed without chemical or biological additives other

than those currently allowed by the State of Alaska solid waste permit. The expanded footprint of the tailings pile would occupy 61 acres.

- **Alternative C** – Alternative C would modify the GPO and realign of the boundaries of the tailing pile footprint displayed in Alternative B to minimize the lease area and the disturbed area within the Admiralty Island National Monument and move the expansion area of the pile away from steeper slopes. Like all alternatives, Alternative C would utilize the post-closure construction of an engineered soil cover on the pile to minimize the transmission of oxygen and water into the pile. Alternative C evaluates the use of a continuous carbon addition to the pile, which helps the sulfate reduction process positively influence water chemistry of the effluent. This alternative would also institute a sulfate reduction monitoring program (SRMP) to determine the additional amount of carbon required to influence post-closure water quality to meet applicable effluent limits in KGCMC's NPDES permit. The purpose of this alternative is to provide more assurance of long-term chemical stability of the tailings than with the proposed action. The expanded footprint of the tailings pile would occupy 62 acres.
- **Alternative D** – Alternative D would modify the general plan of operations to require the addition of carbonate (limestone) into the entire volume of new tailings placed on the pile. The volume of carbonate necessary to neutralize the tailings would expand the footprint of the tailings pile to 81 acres. This option would entail a lease area in the Monument of 115 acres. The purpose of this alternative is to consider an alternate method of increasing the neutralizing potential of the tailings pile beyond what is expected in the proposed action.

This chapter presents the environmental consequences for each alternative and sets forth the following:

- The potential environmental impacts of the alternatives,
- Any adverse environmental impacts that cannot be avoided,
- The relationship between short-term human uses of the environment and the maintenance and enhancement of long-term productivity, and
- Any irreversible or irretrievable commitments of resources.

4.1.1 Effects, Impacts, and Analyses

The Council on Environmental Quality (CEQ) has established regulations for implementing the National Environmental Policy Act of 1972 (NEPA) (40 CFR 1500 – 1508). For this analysis, the study team relied on those definitions as follows:

> The terms "effects" and "impacts" are used interchangeably in this chapter, as they are in the CEQ regulations for implementing the procedural provisions of NEPA (40 CFR §1508.8). The effects (or impacts) examined include ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, heritage, and economic, as well as social effects, or health impacts, whether direct, indirect, or cumulative. These impacts are measurable individually or cumulatively, and if an impact is adverse, it requires avoidance or minimization to mitigate the effect.
>
> The terms "positive" or "beneficial" and "negative" or "adverse " are likewise used interchangeably in this analysis to indicate direction of intensity in significance determination.
>
> In this document, impacts are defined as "those changes to the existing environment that have either a beneficial or adverse consequence as a result of project construction, operation, and maintenance." (40 CFR 1508.8) Impacts are described in terms of frequency, duration, general scope and/or size, and intensity.

The combinations of frequency, duration, scope/size, and intensity of identified adverse impacts are described as follows:

None – (no change) No impacts are anticipated when subject resources are not present or activities are not expected to affect those resources that are present.

Negligible – Impacts on subject resources may occur as a result of project activities, but are not measurable.

Minor – Impacts that are less than significant and do not require avoidance or minimization to mitigate that effect.

Significant – as used in NEPA, is determined by considering the context in which the action will occur and the intensity of the action (40 CFR 1508.27).

Context – The context in which the action will occur includes the specific resources, ecosystem, and the human environment affected. Context is considered on a site-specific project area, and regional basis. Both short- and long-term effects are relevant.

Intensity – This refers to the severity of impact. The intensity of the action includes the type of impact (beneficial versus adverse), duration of impact (short versus long term), magnitude of impact (minor versus major), and degree of risk (high versus low level of probability of an impact occurring). Further tests of intensity for this project include: (1) substantial damage to habitats; (2) impacts on endangered or threatened species, marine mammals, or critical habitat of these species; (3) cumulative adverse effects; (4) impacts on biodiversity and ecosystem function; (5) significant social or economic impacts; and (6) impacts on subsistence.

These impacts have a measurable effect individually or cumulatively, and, if the impact is negative, may require avoidance or minimization to mitigate the effect. Significant adverse impacts are addressed in the following manner:

- Demonstrating that the impact can be reduced to a minor level by changing the project design,
- Demonstrating that the alternative is acceptable because the risk of the impact is small, or
- Demonstrating that the impact cannot be reduced by changes in design.

Direct effects "...are caused by the action and occur at the same time and place." (40 CFR 1508.8)

Indirect effects "...are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems." (40 CFR 1508.8)

Cumulative impact "...is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7).

Each alternative considered in this document would permit operations to continue for approximately two more years. All action alternatives would allow operations to continue for an additional 10 years, based upon known reserves and potentially another 10 years based on reasonable predicted discoveries of new ore. Therefore analyses use a time frame of 22 years, which is the expected life of the mine. Consequently all analyses of impacts throughout this chapter consider the impact of the mine operation in the past, combined with the anticipated impacts of reasonably foreseeable future operations under that alternative.

Past, present, and reasonably foreseeable future impacts included in these analyses are not limited to tailings disposal impacts. Rather, these analyses include consideration of available data and information (such as fresh water monitoring data, management and reclamation plans, and other mitigation measures) in regard to impacts of all mine activities affecting the same environmental resources as the alternatives considered in this document. Such activities include facility construction as well as use and disposition of production rock.

All analyses also consider mitigation resulting from implementation of management plans. These include the Reclamation Plan (KGCMC General Plan of Operations, Appendix 14), contained in Appendix C of this document, and the management tailings section of the KGCMC General Plan of Operations, Appendix 3.

4.1.2 Chapter Organization

This chapter compares potential impacts to environmental resources from the four alternatives. There are parts of the environment that are described in Chapter 3 (location, climate, oceanography, and geology) that will not be impacted by the project. Those parts of the environment are not further described or analyzed in Chapter 4. The remaining parts of the affected environment that have the potential to be affected are analyzed in this chapter in the same order as Chapter 3. In a section for each part of the affected environment, the potential environmental consequences of each alternative are discussed. Where the impacts are the same as previously discussed for an earlier alternative, the consequences are simply described as "Same as…." For a number of resources, none of the alternatives would have a measurable impact. In those cases the lack of impact to all four alternatives is described at once.

4.2 Land

The location of the proposed action in and adjacent to the Admiralty Island National Monument was identified as a significant issue.

Consideration of the values inherent in the Admiralty Island National Monument as shown in Table 4-1, under Alternative A (no action), 38 acres within the Monument are affected. Alternative B (the proposed action) would result in 90 acres in the Monument being affected.

In response to the recognition of Monument values as a significant issue, Alternative C was designed to reduce, from the proposal, leased area in the Monument. Reducing the acres is a way of limiting the intensity of activities in the Monument, and by being a smaller area the time required to return the area to a conditions similar to what existed prior to the activity would be less. This was done by eliminating the proposed quarry area at the southern end of the proposed lease area and by moving the southern half of the proposed reclamation materials storage area outside of the Monument to the northeast corner just outside the current proposed lease area. (See Chapter 2, Figure 2-7).

Under Alternative C, the southern boundary of the proposed lease area would move north, out of the Monument approximately 1,480 feet. This alternative would reduce, from the proposal, both the lease area and the disturbed area within the Monument by approximately 22 acres (to 68 acres), although it would increase the lease area and disturbed area outside the Monument by 5 acres. The net change in lease area inside and outside the Monument would be a decrease of 17 acres.

Alternative D would require the addition of limestone to the tailings. This would result in an expansion in the tailings area to 81 acres. Under this alternative, the tailings facility lease area would expand to 172 and the leased area within the Monument would expand to 115 acres.

This alternative would also require a structure of about 18,000 square feet for dry storage of limestone and equipment for mixing the limestone into the tailings. In addition to the increase of the size of the tailings pile, the dry storage area and mixing equipment would require an expansion of the previously disturbed area for an additional 1 or 2 acre increase in the footprint at the mill or tailings site. As discussed under Alternative C, there are a limited number of areas that the tailings pile can expand into while still addressing other resource concerns.

The area of the tailing pile is not in an inventoried roadless area. No roads connected with this project would be constructed outside of the leased tailing site area.

Table 4-1 Acreages by Alternative

	Total Lease Area After Expansion	Area of Lease Expansion Only	Total Tailings Footprint Area	Total Disturbed Area (est.)	Total Lease Area in Monument	Total Lease Area Outside of Monument
Alternative A – No Action	56	0	29	54	38	18
Alternative B – Proposed action	140	84	61	125	90	50
Alternative C – East Ridge+ the monument values boundary changes + continuous carbon addition	123	67	62	110	68	55
Alternative D – East Ridge+ expanded boundary for room for continuous carbonate addition	172	116	81	162	115	57
(all figures in acres – rounded to the nearest acre)						

4.3 Air Quality

None of the alternatives is expected to have any discernable impact on air quality. Greens Creek Mine facilities are located in a temperate rainforest and thus experiences high precipitation and relative humidity levels that inhibit dust.

4.4 Visual Quality

Travel on the water surface offers direct views of the shoreside loading area and a more indirect view of the tailings facility. The amount of vegetation cleared for the tailings pile would significantly increase with each of the action alternatives, so that a larger gap in the canopy cover would be visible, particularly from the air. The expanded tailings pile would expose a larger area of light-colored soils to those who view the mine facilities from Hawk Inlet.

The discussion of visual effects below applies to all of the alternatives, with exceptions noted at the end of this section. The ability of the proposed expansion of the tailings pile to meet VQO requirements has been determined through the use of existing photographs and photo-simulation.

Existing photographs show the obvious color and texture differences between the bare earth and forested areas. During the first 5 years following closure the landscape will begin to "green-up" but will be obviously different from undisturbed areas. For the next ten years, herbaceous materials will be less dominate and there will be some woody plant growth of pioneer species such as Alder (*Alnus*) and blueberries (*Vaccinium*). Years 15 through 30 will see more woody plants become established and the growth of Spruce (*Picea*) and Hemlock (*Tsuga*) will be visible as a different age and canopy height from the surrounding vegetation. After approximately thirty years the landscape will become more typical of the vegetation common to the undisturbed project area.

The presently approved tailings pile will reach a maximum height of 80 feet above ground level. Under all action alternatives, the pile would be an additional 80 feet higher for a maximum height of 160 feet (approximately 330 feet above sea level). Exposed soil and a break in the canopy will be visible from the water travel routes. (and 4-2). Because of the topography at the water's edge, the tailing pile will be more visible in the middle ground view than it would be from a foreground view (Figure 4-2).

Shoreline views from Hawk Inlet toward the area of the existing tailings pile reveal limited views of the top of the tailings pile and tree boles behind (See). The project area is inventoried as a Type III EVC because the natural appearance of the landscape still remains dominant and the disturbance appears minor to the average forest visitor. Because the disturbance from Alternatives B, C, and D will be visually similar to the existing disturbance from Alternative A, it is predicted that under all alternatives the area will continue to be inventoried as a Type III EVC.

Figure 4-1 **Existing Tailings Pile from Hawk Inlet (Alternative A)Alternative B and C (October, 2003)**

Figure 4-2 **Photo-Simulation of Hawk Inlet showing Alternative B and C Proposed Tailings Expansion at Maximum Height before Revegetation (October 2003)**

Figure 4-3 **Photo-Simulation of Hawk Inlet showing Alternative D Proposed Tailings Expansion at Maximum Height before Revegetation (October, 2003)**

Alternatives B, C, and D would each have greater capacity than the existing lease (Alternative A – no action) and would thus increase the extent and prolong the period of visual impact.

Under all action alternatives, the final height of the pile would be approximately 80 additional feet higher for a pile height level of 160 feet above the ground level and an elevation of 330 feet above sea level. The visual impacts of Alternatives B and C would be essentially similar. Both would have larger footprints than the current permitted pile, (61.3 and 62.2 acres respectively).

The tailings footprint associated with Alternative D would be the same height as Alternatives B and C, but would be another 20 acres larger (81.5 acres) to accommodate the carbonate. Because of the larger size, the visual impact of Alternative D would be the greatest.

The reclamation plan for all alternatives would comply with Appendix 14 of the October 2000 GPO and with the DEC Waste Management Permit. Under all alternatives, the capped pile would have slopes of approximately 3H to 1V. This is steeper than the muskegs and forested slopes between the pile and Hawk Inlet, but is not as steep as some of the forested slopes directly above the location of the finished pile. Overall, the topography of the pile will blend into the hummocks and slopes of the surrounding area. All alternatives are consistent with the Forest Plan for the Non-Wilderness National Monument LUD VQO of Maximum Modification. Approximately 40 years after mining operations have ceased the site would meet the VQO of Retention.

4.5 Geochemistry and Hydrology

Water Quality was identified as a significant issue for this project and it is by far the most complex of the issues addressed in this EIS.

Water quality concerns raised during scoping included the potential for metals loading and/or Acid Rock Drainage (ARD) from the tailings pile, long-term maintenance of surface and groundwater standards, the effectiveness of proposed methods for control of non-contact water, the need to add a monitoring program to measure metals uptake by wetland communities and stream sediments, and bioaccumulation. (USDA, FS, 2001)

The following sections discuss surface and ground water hydrology and geochemistry. Appendix A provides greater detail regarding the stochastic modeling and technical basis of the conclusions presented here.

This section discusses the potential impacts of the four project alternatives on the *hydrology* (water quantity and quality) of the tailings pile area. Surface water and groundwater in the Tributary Creek, Cannery Creek, and Hawk Inlet drainages could be affected by each of the project alternatives.

Activities that could affect groundwater quantity include increased acreage of the tailings pile footprint, surface water diversion channels around the perimeter of the pile, slurry walls constructed to divert upgradient groundwater around the pile, and the engineered liner underneath the pile. Groundwater flow regimes in the Tributary Creek, Cannery Creek and Hawk Inlet drainages could be affected by these activities.

Activities that could affect surface water and groundwater quality include tailings placement and surface reclamation. These activities will result in geochemical and biological processes occurring within the tailings pore water, and geochemical and physical processes that occur on the surface of the pile. These processes affect surface water and/or groundwater quality.

Due to the complex nature of the geochemical and biological processes within the tailings, and the hydrologic connections between groundwater and surface water downgradient of the tailings, a water quality assessment model was independently developed specifically for this EIS to predict the potential impacts of the various project alternatives to receiving waters. For quality assurance, this model was also compared against the model developed by Environmental Design Engineering (EDE, 2002b), which predicts water quality emanating from the Alternative C tailings pile without soil amendments at post-closure, once the geochemistry of the tailings reaches a hydrologic and geochemical steady state condition.

The model developed for this EIS (Appendix A) uses input data collected at the site and is also based on geochemical, oxygen flux, and unsaturated flow principals. However, it differs from the EDE model in two important ways. The model is a probability model and provides water quality predictions with different degrees of likelihood. The model also predicts the quality of water draining from the pile over time, beginning at the onset of closure (completion of the pile cover) and continuing into the post-closure period. Similar to the EDE model, this model also predicts water quantity and quality flowing out of the tailings pile. Those predictions are then combined with the quantity and quality of potential receiving waters to predict a resulting water quality. The quality of this water was then compared to the AWQS for fresh and marine waters.

The stochastic model predicts changes in water chemistry through time based on the conceptual understanding of chemical and physical processes described by KGCMC in the geochemistry baseline report. The model (Figure 4-4) assumes that as rainfall infiltrates through the engineered cover, it displaces the water that is already in the pile downward. Therefore, the rate of water flowing out of the tailings is determined by the rate of infiltration of water into the tailings. The model predicts that the water that is initially held in the tailings piles will be pushed out of the pile after about 50 to 100 years.

The water quality for the first 50 to 100 years is determined by the chemistry of water already held within the pile. In the time frame of 50 to 500 years, the quality of water emanating from the pile will be determined by the geochemical conditions that prevail after closure. The primary changes in geochemical and hydrologic conditions that are anticipated to occur after closure include a reduction in the supply of oxygen, a reduction in the infiltration of water (compared to infiltration during operation of the mine), and a reduction in the supply of carbon.

The model accounts for potential acidification by calculating the time period required for tailings to acidify. These calculations indicate that acidification will not occur within the model evaluation period. The model also accounts for metal leaching potential. Metal leaching is associated with oxidation of the tailings. While water currently exiting the pile is thought to be *reduced* (and to have low metal content), the model accounted for future oxidation of the pile. In the long-term, metal leaching will be limited by the low rate of oxygen entry into the pile. The engineered cover will limit the oxygen supply after closure to a few grams per square meter per year.

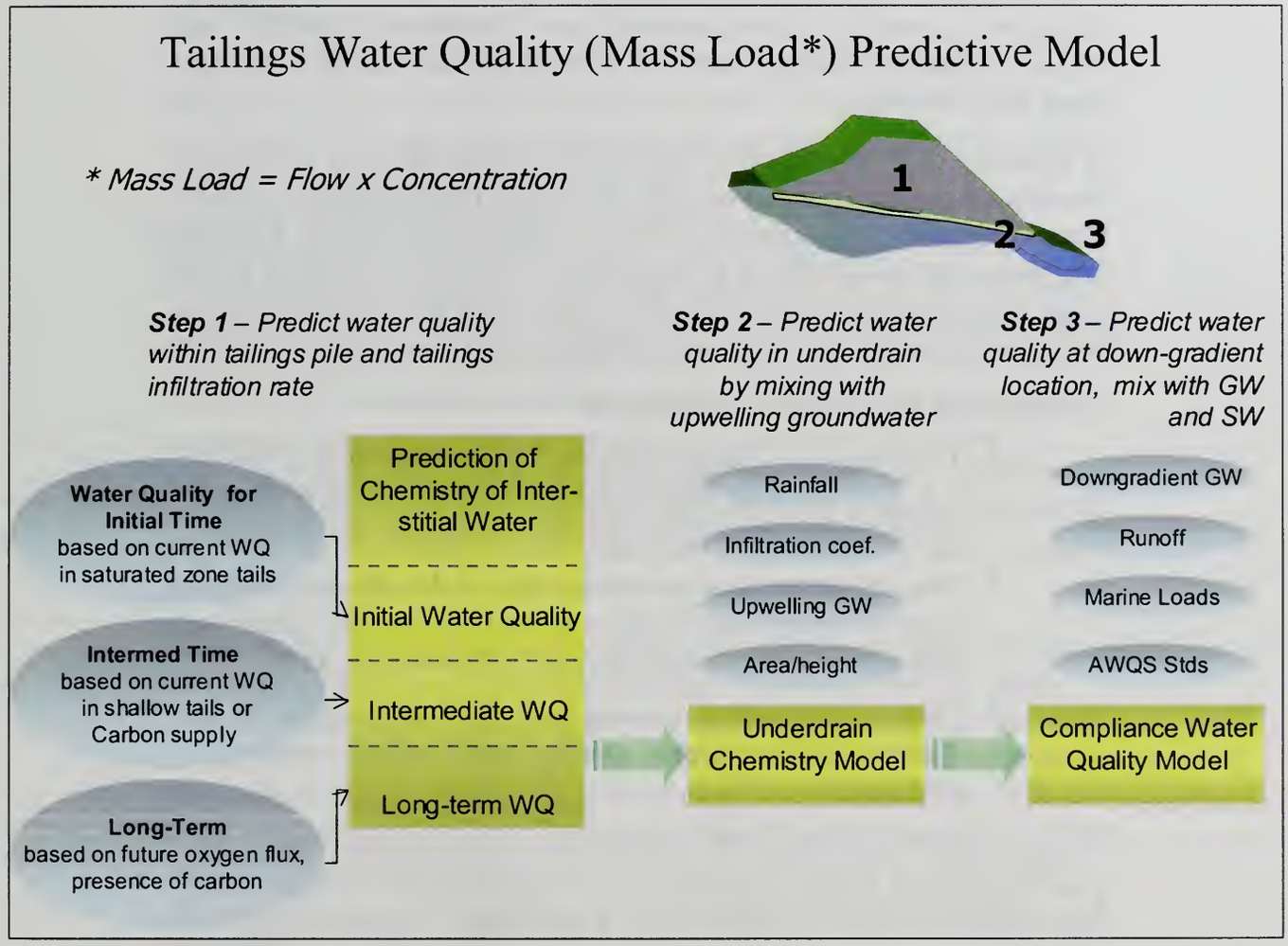
The model also accounts for leaching metals that may accumulate due to oxidation of the tailings that occurs prior to placement of the cover. For Alternative C, the model accounts for a sufficient source of available carbon to promote sulfate reduction (as discussed in Sections 3.7 and 3.8) within the pile. Reactions over a variety of durations are analyzed in the model.

The model determines water quality through time, based on the amount of leaching that occurs. The model accounts for shorter time required to displace the water initially held in the pile from the thinner pile edges. This is accomplished by incorporating the pile area and thickness into the model.

The model also accounts for the variation in groundwater flow at the site. The underdrains collect a combination of tailings water and groundwater

that flows upward into the drain. The rate of groundwater flow into the drain was predicted on the basis of observed flow rates in the wet wells. Since the groundwater flow rate was observed to vary seasonally, the rate of groundwater movement was variable. The resulting prediction of water quality in the underdrains, therefore, represents *instantaneous concentration* (the concentration that might be observed during any sampling event) as opposed to a long-term average concentration.

Figure 4-4 Schematic of the predictive model developed by the EIS team to assess potential water quality impacts for each alternative



The model also considers the potential for dilution of underdrain water with the groundwater system downgradient of the pile and with surface runoff from the pile. The amount of dilution water available is based on the understanding of the surface water and groundwater systems in the Hawk Inlet drainage basin presented in Chapter 3 of this document. The most probable amount of combined flow from the underdrain flow and from surface and groundwater dilution varies from 88 to 172 gpm for the

various alternatives. It is unknown if the downgradient groundwater system would be able to accommodate flows of this magnitude.

Treated water from the tailings is currently discharged through a diffuser into Hawk Inlet under a NPDES discharge permit. The model compares the load (in kg per day) of key metals in the underdrain water to the loading allowed in the facility discharge permit.

The model was used to evaluate Alternatives A through D. The stochastic nature of this model allows water quality to be predicted for a *most probable* case (50 percent probability, plus or minus one standard deviation), as well as a *lowest probable* case (5 percent probability), and a *highest probable* case (95 percent) for model runs simulating 5 to 2500 years after closure.

A summary of the model results is described below for each alternative. Results are shown for common ions and certain metals, including those that are currently monitored as part of the mine's water quality monitoring program or are monitored as a requirement of the mine's NPDES permit. Probability results are given for several distinct time periods, beginning shortly after closure is completed, and continuing over hundreds of years.

Water quality predictions are shown for:

- Discharge/compliance scenario 1(a), as described in Section 2.2 (flow from the underdrain (combination of upwelling groundwater and tailings seepage discharged to freshwater)
- Discharge/compliance scenario 1(b) as described in Section 2.2 (flow from the underdrain combined with surface runoff water and groundwater and discharged to freshwater); and
- Discharge/compliance scenarios 2 and 3 as described in Section 2.2 (discharge to marine water, without or with a diffuser).

For the case where tailings effluent combines with surface water and groundwater, the working assumption is that dilution water blends with the underdrain water upgradient from a compliance location prescribed by the regulatory agencies. This could be accomplished using a treatment works that would utilize various chemical and physical processes such as oxidation, adsorption, dilution and dispersion that may occur in surface water or groundwater downgradient of the tailings facility.

The results of the water quality modeling do not reflect a change in water chemistry resulting from active (i.e., chemical precipitation) water treatment. As described in Chapter 2, KGCMC will continue an

appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

A complete technical description of the model and model output is contained in Appendix A.

4.5.1 Alternative A

Under the No Action Alternative, surface water flows in Tributary Creek, Cannery Creek, and Greens Creek will be unchanged from their present amount.

Impacts to surface water quantity in the three receiving drainages will be minor during the operations and closure phases. Upgradient surface water will continue to be diverted around the tailings pile into the three adjacent drainages. Surface water runoff from the pile will continue to be collected, treated, and discharged into Hawk Inlet under the NPDES permit. During the post-closure period, the surface water diversion and collection system would be managed so that surface water could either be (1) allowed to flow naturally as topographic contours dictate into the three receiving drainages, in which case there would be no effect on surface water quantity in the three adjacent drainages; or (2) routed towards the southwest corner of the pile to combine with the underdrain flow, in which case there would be a minor decrease in surface water quantity available to the Tributary Creek and Cannery Creek drainages due to the slight decrease in tributary area. From here, the combined water will be managed using discharge scenario 1b as described in Section 2.2.

Under the No Action Alternative, during operations, precipitation will continue to infiltrate and percolate through the pile to the water table inside the pile, and ultimately to the wet wells where it will be collected and routed to the treatment plant. Upwelling groundwater will continue to mix with infiltrated water in the underdrains, be collected by the wet wells, and be treated prior to discharge to Hawk Inlet. Reclamation of the pile will result in a continuation of the groundwater and surface water flow patterns and water quality patterns that have developed during operations.

Water quality data from the Pit 5 area show the presence of elevated sulfate levels in the bedrock groundwater aquifer. There are no known current impacts to Cannery Creek or the adjacent high quality wetlands, and low permeability sediments are present to exclude most or all of the contact water and flow in this direction. Under this alternative, groundwater in this area would continue to have the potential to flow, as it currently does, towards Cannery Creek.

There would be no effect on the water quality in the Tributary Creek drainage.

Results from the water quality model for Alternative A are shown in Figure 4-5 and Table 4-2. Results indicate that exceedances to fresh water AWQS (discharge scenario 1(a) without dilution) for sulfate and antimony are initially predicted for underdrain water. After 25 years, antimony levels should have dropped below AWQS, but selenium may increase and could exceed AWQS. After 200 years, sulfate should decline below AWQS; however, zinc concentrations are predicted to have risen above AWQS. After 500 years, cadmium levels may be above AWQS. Without treatment, none of these substances exceeds AWQS initially at the compliance point where underdrain flow mixes with surface water and groundwater (discharge scenario 1(b) with dilution), but selenium, zinc and cadmium levels are predicted to have exceeded AWQS after 100, 350, and 1000 years, respectively. Selenium levels are predicted to have fallen back below AWQS after 350 years. These predicted exceedances of AWQS under discharge scenario 1 may impair existing protected water use classes if discharged without treatment. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Model results compared to AWQS for marine water (discharge scenario 2) using a 50:1 dilution show there are no exceedances. The current KGCMC mixing zone provides a 170:1 dilution; this represents a 70 percent reduction in the mixing zone size.

The predicted load of metals was compared to the currently allowable loads under the existing discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than one percent of allowable loads for Alternative A for all metals in the permit.

Effects to water quality in the Hawk Inlet drainage would be considered significant if tailings effluent is discharged (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be negligible adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater or marine water.

Table 4-2 Alternative A Water Quality Model

Alternative A -Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS	250			6 to 9	0.050	0.0003 to 0.0006	0.164 to 0.382
5	**286**	61	7.0	110	0.007	0.0001	0.020
25	**285**	90	6.9	103	0.007	0.0001	0.093
50	**282**	119	6.8	92	0.007	0.0002	0.171
100	**266**	172	6.8	76	0.006	0.0004	0.317
200	205	177	6.8	65	0.006	0.0005	0.428
350	118	122	6.9	64	0.005	0.0005	0.443
500	70	91	6.9	66	0.005	**0.0005**	0.439
1000	25	61	7.0	70	0.005	**0.0005**	0.428
2500	16	53	7.0	80	0.005	**0.0005**	0.419
Tailings Seepage (gpm)		5.3					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		34.0					

Alternative A - Discharge/Compliance Scenario 1(b) – Predicted Concentration at Fresh water Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed Chronic Fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
Background	6	22	7.0	66	0.005	0.00004	0.0025
AWQS	250			6 to 9	0.050	0.0002 to 0.0004	0.106 to 0.241
5	129	36	7.0	76	0.006	0.0001	0.011
25	129	50	6.9	72	0.006	0.0001	0.044
50	126	64	6.9	68	0.005	0.0001	0.080
100	121	87	6.8	60	0.005	0.0002	0.144
200	94	90	6.8	55	0.005	0.0002	0.189
350	54	65	6.9	55	0.005	0.0002	0.196
500	34	50	6.9	55	0.005	0.0002	0.194
1000	13	36	7.0	57	0.005	0.0002	0.186
2500	9	33	7.0	62	0.005	0.0002	0.184
Downgradient GW (gpm)		27.5					
Downgradient SW (gpm)		26.6					
Total Flow (gpm)		88.1					

Alternative A - Discharge/Compliance Scenario 2 - Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS	NA	NA	6 to 9	NA	1.8	0.4	4.1
5	286	61	7.0	110	0.007	0.0001	0.020
25	285	90	6.9	103	0.007	0.0001	0.093
50	282	119	6.8	92	0.007	0.0002	0.171
100	266	172	6.8	76	0.006	0.0004	0.317
200	205	177	6.8	65	0.006	0.0005	0.428
350	118	122	6.9	64	0.005	0.0005	0.443
500	70	91	6.9	66	0.005	0.0005	0.439
1000	25	61	7.0	70	0.005	0.0005	0.428
2500	16	53	7.0	80	0.005	0.0005	0.419
Tailings Seepage (gpm)		5.3					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		34.0					

NOTE: For all alternatives and tables - the hardness downgradient of the tailings facility was calculated in the mass load model. Consequently, the predicted hardness used to calculate allowable metal concentrations was the predicted hardness in the combined drain water and receiving water.

Table 4-2 (continued) Alternative A Water Quality Model

Alternative A - Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
AWQS	0.006	0.102 to 0.231	0.0125 to 0.0293	0.0038 to 0.0109	0.00077	0.072 to 0.168	0.005	0.007 to 0.037
5	0.006	0.0003	0.0007	0.0003	<0.000008	0.003	0.002	<0.00005
25	0.006	0.0003	0.0007	0.0003	<0.000008	0.003	0.006	<0.00005
50	0.005	0.0003	0.0007	0.0004	<0.000008	0.004	0.009	<0.00005
100	0.004	0.0004	0.0007	0.0004	<0.000008	0.006	0.016	<0.00005
200	0.003	0.0004	0.0007	0.0004	<0.000008	0.006	0.016	<0.00005
350	0.003	0.0004	0.0007	0.0004	<0.000008	0.005	0.010	<0.00005
500	0.003	0.0004	0.0007	0.0004	<0.000008	0.005	0.006	<0.00005
1000	0.003	0.0004	0.0007	0.0004	<0.000008	0.004	0.002	<0.00005
2500	0.003	0.0004	0.0007	0.0004	<0.000008	0.003	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	5.3
Upwelling GW (gpm)	28.7
Total Flow (gpm)	34

Alternative A - Discharge/Compliance Scenario 1(b) Predicted Concentration at Fresh Water Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
Background	0.0004	0.0002	0.0002	0.0001	0.000004	0.002	0.001	0.00004
AWQS	0.006	0.067 to 0.148	0.0080 to 0.0184	0.0020 to 0.0055	0.00077	0.047 to 0.106	0.005	0.0028 to 0.0147
5	0.003	0.0003	0.0004	0.0002	<0.000008	0.002	0.001	<0.00005
25	0.003	0.0003	0.0004	0.0002	<0.000008	0.002	0.003	<0.00005
50	0.002	0.0003	0.0004	0.0002	<0.000008	0.002	0.005	<0.00005
100	0.002	0.0003	0.0004	0.0002	<0.000008	0.003	0.007	<0.00005
200	0.002	0.0003	0.0004	0.0002	<0.000008	0.003	0.007	<0.00005
350	0.001	0.0003	0.0004	0.0002	<0.000008	0.003	0.004	<0.00005
500	0.001	0.0003	0.0004	0.0002	<0.000008	0.003	0.003	<0.00005
1000	0.001	0.0003	0.0004	0.0002	<0.000008	0.002	0.001	<0.00005
2500	0.001	0.0003	0.0004	0.0002	<0.000008	0.002	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Downgradient GW (gpm)	27.5
Downgradient SW (gpm)	26.6
Total Flow (gpm)	88.1

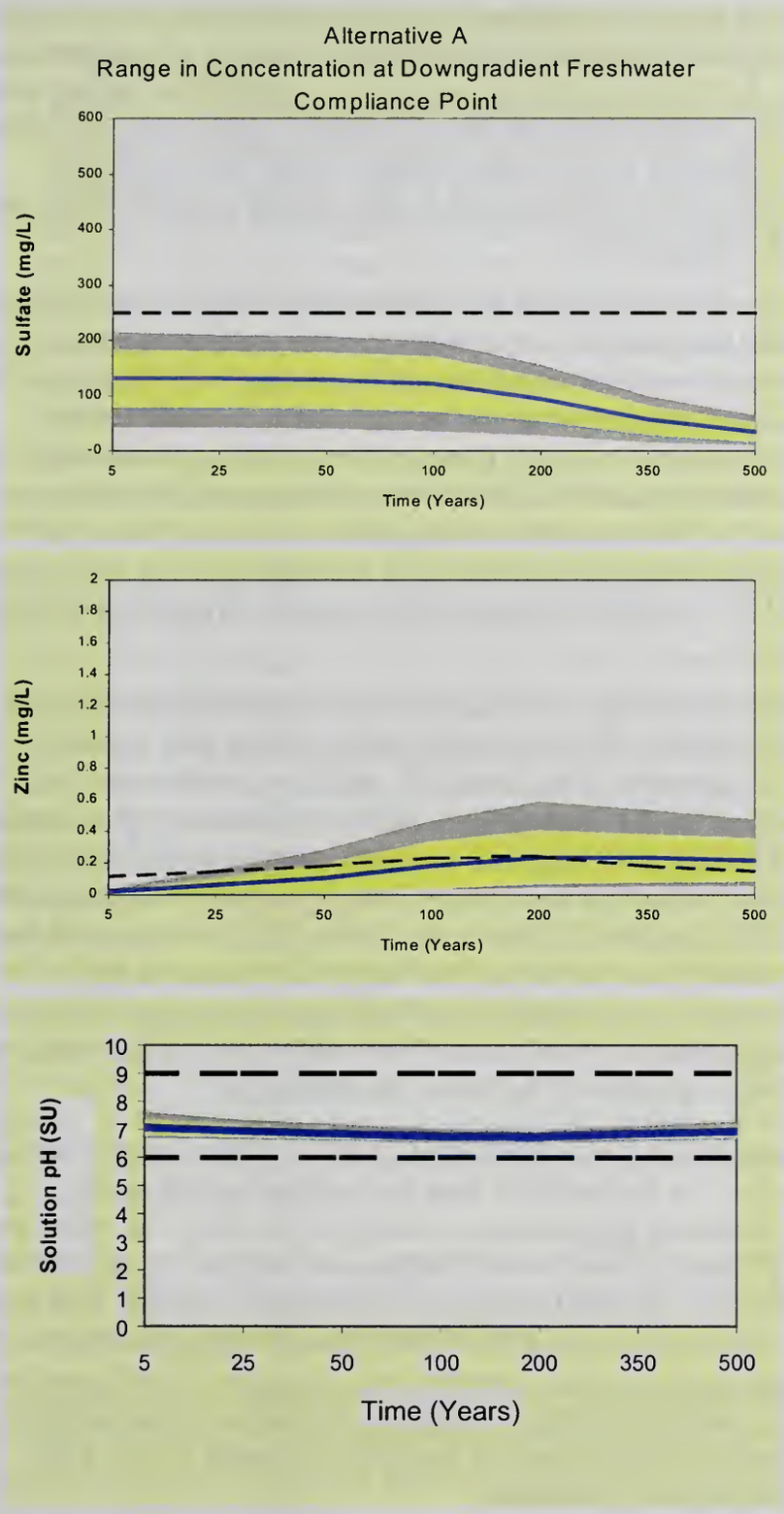
Alternative A - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
AWQS	NA	NA	0.155	0.405	0.0470	0.410	3.550	0.095
5	0.0061	0.0003	0.0007	0.0003	<0.000008	0.003	0.002	<0.00005
25	0.0057	0.0003	0.0007	0.0003	<0.000008	0.003	0.006	<0.00005
50	0.0051	0.0003	0.0007	0.0004	<0.000008	0.004	0.009	<0.00005
100	0.0041	0.0004	0.0007	0.0004	<0.000008	0.006	0.016	<0.00005
200	0.0032	0.0004	0.0007	0.0004	<0.000008	0.006	0.016	<0.00005
350	0.0030	0.0004	0.0007	0.0004	<0.000008	0.005	0.010	<0.00005
500	0.0030	0.0004	0.0007	0.0004	<0.000008	0.005	0.006	<0.00005
1000	0.0030	0.0004	0.0007	0.0004	<0.000008	0.004	0.002	<0.00005
2500	0.0030	0.0004	0.0007	0.0004	<0.000008	0.003	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	5.3
Upwelling GW (gpm)	28.7
Total Flow (gpm)	34

Figure 4-5 Alternative A – Range in Concentration at Compliance Point



4.5.2 Alternative B - Proposed Action

The expanded area of this alternative would decrease the tributary area to the three adjacent drainages by an additional 3 percent as compared to Alternative A. During operations and closure, slightly less surface water will flow into the three adjacent drainages than occurs under Alternative A. Overall, effects to surface water quantity in the three receiving drainages during the operations and closure phases would be the same as those under Alternative A

During the post-closure period, the surface water diversion and collection system would be managed so that surface water could either be (1) routed towards the southwest corner of the pile to combine with the underdrain flow, in which case there would be a minor effect on surface water quantity in Tributary Creek and Cannery Creek drainages due to the slight decrease in tributary area (less than 1 percent compared to Alternative A); or (2) allowed to flow naturally as topographic contours dictate into the three receiving drainages (the same as in Alternative A), in which case there would be no effect on surface water quantity in the three adjacent drainages.

Expansion of the tailings pile to the west as described under the proposed action would result in the placement of tailings in an area currently occupied by peat deposits and relatively shallow groundwater. The proposed action would result in an incremental increase in groundwater capture and discharge through the wet wells and treatment system. During operation and closure this would have a negligible effect on groundwater quantity as compared to Alternative A. During the post-closure period, underdrain water from the tailings pile might be released to the groundwater system in the Hawk Inlet drainage, resulting in a minor increase in groundwater in this area. This would have a minor effect on the groundwater quantity in the Hawk Inlet drainage.

Under Alternative B, the bedrock knoll in the northwest corner would be covered with a low permeability liner and tailings, which would effectively eliminate groundwater recharge in that area. The water level in the bedrock under the knoll would decline, and the driving forces for groundwater flow towards Cannery Creek would be reduced. Due to the relatively small area involved, this would have a negligible effect on the groundwater quantity in the Cannery Creek drainage. This alternative would have a beneficial effect of reducing the potential discharge of groundwater with elevated sulfate levels into Cannery Creek or the associated high quality wetlands.

The effects on the groundwater quality in the Tributary Creek drainage surface water in the Hawk Inlet drainage and marine water in Hawk Inlet would be the same as those identified under Alternative A, that is:

> Effects to water quality in the Hawk Inlet drainage would be considered significant if tailings effluent is discharged (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be negligible adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater or marine water.

Results from the water quality model for Alternative B are shown in Figure 4-6 and Table 4-3. Results are similar to those for Alternative A, indicating that sulfate and antimony would initially exceed fresh water AWQS in the underdrain flow without dilution, (discharge scenario 1(a)). After 25 years, increased selenium levels are predicted to have exceeded AWQS in the underdrain. After 100 years, cadmium and zinc levels are predicted to have exceeded AWQS. Antimony and sulfate concentrations are expected to have dropped below AWQS after 200 years, followed by selenium after 500 years. Without treatment, only sulfate would initially exceed fresh water AWQS with dilution under discharge scenario 1(b), but selenium, zinc and cadmium are expected to be in exceedence of fresh water AWQS at 25, 200 and 500 years, respectively. These predicted exceedances of AWQS under discharge/compliance scenario 1 would impair existing protected water use classes if discharged without treatment. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Model results for Alternative B compared to AWQS for marine water using a 50:1 dilution (Discharge/Compliance Scenario 2) are the same as for Alternative A, indicating no exceedances.

The predicted load of metals was compared to the currently allowable loads under the NPDES discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than 1 percent of allowable loads for Alternative B for all metals in the permit.

Like Alternative A, effects to water quality in the Hawk Inlet drainage would be considered significant if tailings effluent is discharged (without

treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to these receiving waters (discharge scenario 1). There would be negligible adverse effects if tailings effluent is discharged without treatment directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects if tailings effluent is discharged without treatment through the diffuser into Hawk Inlet (discharge scenario 3). If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater or marine water.

Table 4-3 Alternative B Water Quality Model

Alternative B - -Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic Freshwater dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS	250			6 to 9	0.050	0.0005 to 0.0006	0.258 to 0.382
5	616	102	7.1	160	0.011	0.0001	0.040
25	619	165	6.9	142	0.010	0.0003	0.200
50	606	229	6.8	121	0.009	0.0005	0.376
100	568	347	6.6	86	0.008	0.0008	0.699
200	429	355	6.6	63	0.006	0.0011	0.940
350	243	239	6.8	63	0.006	0.0011	0.959
500	144	170	6.9	65	0.006	0.0011	0.954
1000	46	105	7.1	73	0.006	0.0011	0.918
2500	28	89	7.1	92	0.006	0.0011	0.907
Tailings Seepage (gpm)		15.3					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		44.0					

Alternative B - Discharge/Compliance Scenario 1(b) Predicted Concentration at Freshwater Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic freshwater dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
Background	6	22	7.1	66	0.005	0.00004	0.0027
AWQS	250		6 to 9		0.050	0.0003 to 0.0006	0.158 to 0.382
5	285	56	7.0	97	0.007	0.0001	0.018
25	288	88	6.9	88	0.006	0.0001	0.085
50	283	116	6.8	77	0.006	0.0002	0.160
100	262	167	6.7	59	0.006	0.0004	0.293
200	197	170	6.7	49	0.005	0.0005	0.388
350	109	117	6.8	49	0.005	0.0005	0.406
500	63	86	6.9	50	0.005	0.0005	0.401
1000	22	57	7.0	54	0.005	0.0005	0.394
2500	15	51	7.0	65	0.005	0.0005	0.386
Downgradient GW (gpm)		27.5					
Downgradient SW (gpm)		74.6					
Total Flow (gpm)		146.1					

Alternative B - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS (yr 50)	NA	NA	6 to 9	NA	1.8	0.4	4.1
5	616	102	7.1	160	0.011	0.0001	0.040
25	619	165	6.9	142	0.010	0.0003	0.200
50	606	229	6.8	121	0.009	0.0005	0.376
100	568	347	6.6	86	0.008	0.0008	0.699
200	429	355	6.6	63	0.006	0.0011	0.940
350	243	239	6.8	63	0.006	0.0011	0.959
500	144	170	6.9	65	0.006	0.0011	0.954
1000	46	105	7.1	73	0.006	0.0011	0.918
2500	28	89	7.1	92	0.006	0.0011	0.907
Tailings Seepage (gpm)		15.3					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		44.0					

Table 4-3 (continued) Alternative B Water Quality Model

Alternative B - Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
AWQS	0.006	0.158 to 0.231	0.0197 to 0.0293	0.0067 to 0.0109	0.00077	0.113 to 0.168	0.005	0.017 to 0.037
5	0.0124	0.0004	0.0013	0.0005	<0.00002	0.003	0.003	<0.00005
25	0.0116	0.0004	0.0014	0.0006	<0.00002	0.005	0.011	<0.00005
50	0.0107	0.0005	0.0013	0.0007	<0.00002	0.007	0.019	<0.00005
100	0.0084	0.0005	0.0013	0.0007	<0.00002	0.010	0.033	<0.00005
200	0.0061	0.0005	0.0012	0.0007	<0.00002	0.011	0.034	<0.00005
350	0.0058	0.0005	0.0012	0.0007	<0.00002	0.009	0.020	<0.00005
500	0.0058	0.0005	0.0012	0.0007	<0.00002	0.008	0.011	<0.00005
1000	0.0058	0.0005	0.0012	0.0007	<0.00002	0.006	0.003	<0.00005
2500	0.0058	0.0005	0.0012	0.0007	<0.00002	0.006	0.002	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	15.3
Upwelling GW (gpm)	28.7
Total Flow (gpm)	44

Alternative B - Discharge/Compliance Scenario 1(b) Predicted Concentration at Fresh Water Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
Background	0.0004	0.0002	0.0002	0.0001	0.000004	0.001	0.001	0.00004
AWQS	0.006	0.098 to 0.231	0.0120 to 0.0293	0.0032 to 0.0109	0.00077	0.069 to 0.168	0.005	0.0062 to 0.0374
5	0.005	0.0003	0.0007	0.0003	<0.00001	0.002	0.002	<0.00005
25	0.005	0.0003	0.0007	0.0003	<0.00001	0.003	0.005	<0.00005
50	0.005	0.0003	0.0007	0.0003	<0.00001	0.004	0.009	<0.00005
100	0.004	0.0003	0.0007	0.0004	<0.00001	0.005	0.014	<0.00005
200	0.003	0.0004	0.0006	0.0004	<0.00001	0.006	0.015	<0.00005
350	0.003	0.0004	0.0006	0.0004	<0.00001	0.005	0.009	<0.00005
500	0.003	0.0004	0.0006	0.0004	<0.00001	0.004	0.005	<0.00005
1000	0.003	0.0004	0.0006	0.0004	<0.00001	0.003	0.002	<0.00005
2500	0.003	0.0004	0.0006	0.0004	<0.00001	0.003	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Downgradient GW (gpm)	27.5
Downgradient SW (gpm)	74.6
Total Flow (gpm)	146.1

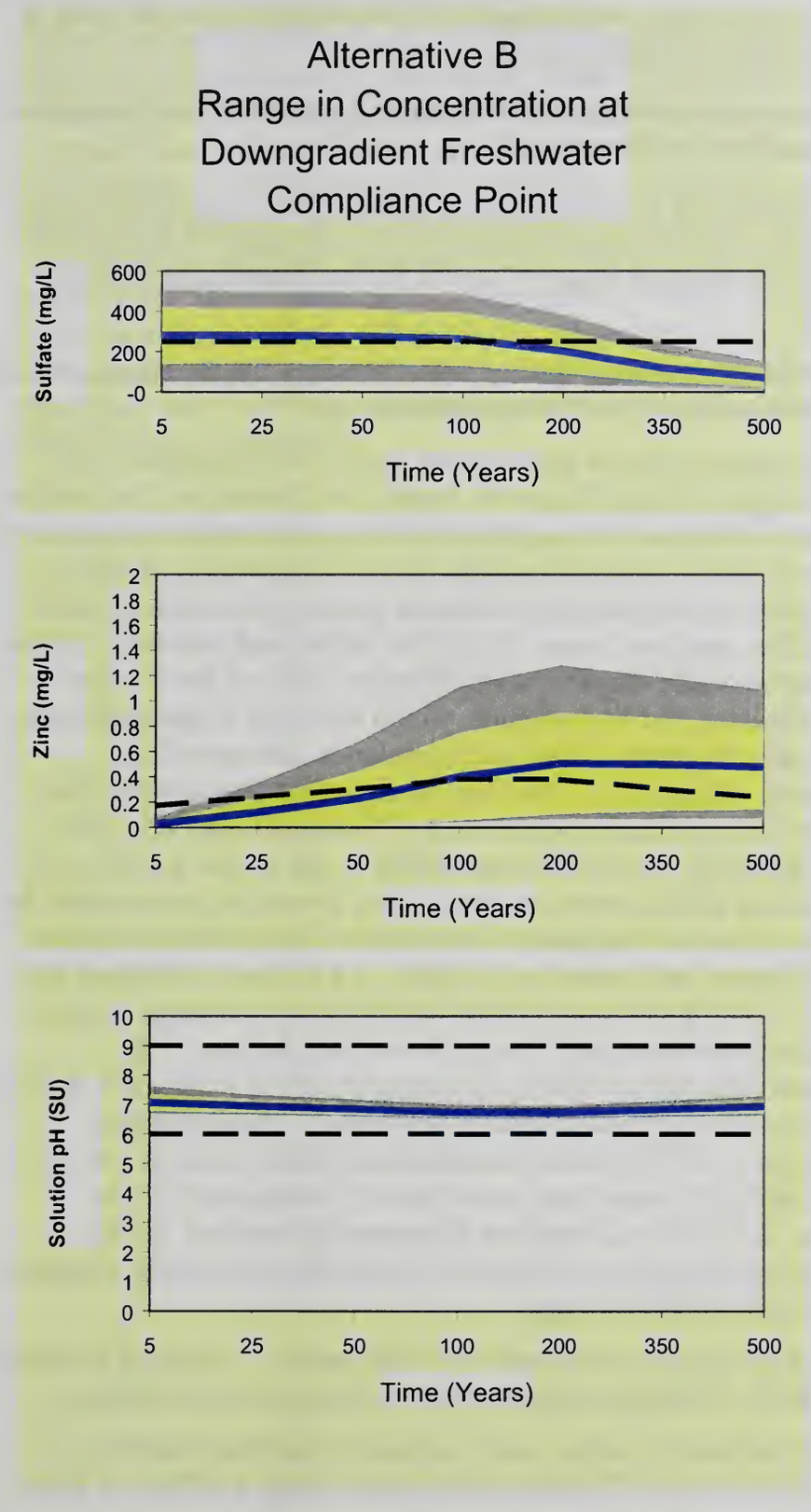
Alternative B - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver
AWQS	NA	NA	0.155	0.405	0.0470	0.410	3.550	0.095
5	0.0124	0.0004	0.0013	0.0005	<0.00002	0.003	0.003	<0.00005
25	0.0116	0.0004	0.0014	0.0006	<0.00002	0.005	0.011	<0.00005
50	0.0107	0.0005	0.0013	0.0007	<0.00002	0.007	0.019	<0.00005
100	0.0084	0.0005	0.0013	0.0007	<0.00002	0.010	0.033	<0.00005
200	0.0061	0.0005	0.0012	0.0007	<0.00002	0.011	0.034	<0.00005
350	0.0058	0.0005	0.0012	0.0007	<0.00002	0.009	0.020	<0.00005
500	0.0058	0.0005	0.0012	0.0007	<0.00002	0.008	0.011	<0.00005
1000	0.0058	0.0005	0.0012	0.0007	<0.00002	0.006	0.003	<0.00005
2500	0.0058	0.0005	0.0012	0.0007	<0.00002	0.006	0.002	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	15.3
Upwelling GW (gpm)	28.7
Total Flow (gpm)	44

Figure 4-6 Alternative B – Range in Concentration at Compliance Point



4.5.3 Alternative C

The effects on surface water quantity for Alternative C are the same as those identified for Alternative B.

The effects on groundwater quantity under Alternative C are the same as those identified for Alternative B.

As with Alternative B, this alternative reduces the potential discharge of groundwater with elevated sulfate levels from the bedrock knob in the northwest corner into Cannery Creek or the associated high quality wetlands.

The effect on groundwater quality in the Tributary Creek drainage would be the same as those identified for Alternative A.

Summary results from the water quality model for Alternative C are shown in Figure 4-7 and Table 4-4. Results for Alternative C reflect the fundamental difference in long-term chemistry that would result from the addition of carbon to the tailings pile. As with Alternatives A and B, initially water in the underdrains without dilution (discharge scenario 1(a)) could exceed fresh water AWQS for sulfate and antimony. Sulfate concentration would decrease after 200 years to below fresh water AWQS. Elevated zinc and selenium would not occur in the underdrain water because on-going sulfate reduction tends to remove these constituents. Antimony, on the other hand, is not affected by sulfate reduction, and may increase as a result of biological reduction. The elevated antimony concentration predicted by the model is likely to be removed from solution when the water from the underdrain contacts the air, causing iron and manganese compounds to chemically precipitate, adsorb antimony, and settle from solution. All of these substances are expected to meet fresh water AWQS with dilution (discharge scenario 1(b)) at the compliance point except for sulfate. Sulfate, at the compliance point using dilution, is marginally above fresh water AWQS for the first 50 to 100 years (without treatment). These predicted exceedances of AWQS under discharge/compliance scenario 1 would impair existing protected water use classes if discharged without treatment. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Results of the water quality model for Alternative C compared to marine water AWQS (discharge scenario 2) show there are no exceedances.

The predicted load of metals was compared to the loads currently allowable under the NPDES discharge permit using a diffuser in Hawk

Inlet. Predicted loads were less than 0.1 percent of allowable loads for Alternative C for all metals in the permit.

Effects to water quality in the Hawk Inlet drainage are considered *minor* (compared to *significant* for Alternatives A and B) for the case where tailings effluent is discharged directly (without treatment) to surface water or groundwater without dilution, or diluted (without treatment) with surface water or groundwater prior to discharge to receiving waters (discharge scenario 1). If water treatment were continued in perpetuity, there would be negligible adverse effects to the receiving surface water or groundwater. There would be negligible adverse effects to marine water for the case where tailings effluent is discharged directly to Hawk Inlet (discharge scenario 2). There would be negligible adverse effects for the case where tailings effluent is discharged through a diffuser into Hawk Inlet (discharge scenario 3).

Table 4-4 Alternative C Water Quality Model

Alternative C - Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic freshwater dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS	250			6 to 9	0.050	0.0005 to 0.0005	0.254 to 0.261
5	616	90	7.1	162	0.010	0.0001	0.006
25	587	90	7.1	162	0.010	0.0001	0.006
50	550	90	7.1	163	0.010	0.0001	0.006
100	483	90	7.1	163	0.010	0.0001	0.006
200	339	89	7.1	162	0.010	0.0001	0.006
350	196	88	7.1	161	0.010	0.0001	0.006
500	117	87	7.1	161	0.010	0.0001	0.006
1000	41	87	7.1	162	0.010	0.0001	0.006
2500	27	87	7.1	162	0.010	0.0001	0.006
Tailings Seepage (gpm)		15.6					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		44.3					

Alternative C - Discharge/Compliance Scenario 1(b) Predicted Concentration at Freshwater Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic freshwater dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
Background	6	22	7.1	66	0.005	0.00004	0.0026
AWQS	250			6 to 9	0.050	0.0003 to 0.0003	0.151 to 0.153
5	290	48	7.0	99	0.007	0.0001	0.003
25	277	48	7.0	100	0.007	0.0001	0.003
50	260	48	7.0	100	0.007	0.0001	0.003
100	227	48	7.0	100	0.007	0.0001	0.003
200	162	49	7.0	100	0.007	0.0001	0.003
350	87	48	7.0	101	0.007	0.0001	0.003
500	52	49	7.0	101	0.007	0.0001	0.003
1000	20	49	7.0	100	0.007	0.0001	0.003
2500	15	49	7.0	100	0.007	0.0001	0.003
Downgradient GW (gpm)		27.5					
Downgradient SW (gpm)		80.0					
Total Flow (gpm)		151.8					

Alternative C - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS (yr 50)	NA	NA	6 to 9	NA	1.8	0.4	4.1
5	616	90	7.1	162	0.010	0.0001	0.006
25	587	90	7.1	162	0.010	0.0001	0.006
50	550	90	7.1	163	0.010	0.0001	0.006
100	483	90	7.1	163	0.010	0.0001	0.006
200	339	89	7.1	162	0.010	0.0001	0.006
350	196	88	7.1	161	0.010	0.0001	0.006
500	117	87	7.1	161	0.010	0.0001	0.006
1000	41	87	7.1	162	0.010	0.0001	0.006
2500	27	87	7.1	162	0.010	0.0001	0.006
Tailings Seepage (gpm)		15.6					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		44.3					

Table 4-4 (continued) Alternative C Water Quality Model

Alternative C - Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
AWQS	0.006	0.155 to 0.160	0.0194 to 0.0199	0.0066 to 0.0069	0.00077	0.112 to 0.115	0.005	0.016 to 0.017
5	0.013	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
25	0.013	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
50	0.013	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
100	0.013	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
200	0.012	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
350	0.012	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
500	0.012	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
1000	0.012	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
2500	0.012	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	15.6
Upwelling GW (gpm)	28.7
Total Flow (gpm)	44.3

Alternative C - Discharge/Compliance Scenario 1(b) Predicted Concentration at Fresh Water Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
Background	0.0004	0.0002	0.0002	0.0001	0.000004	0.001	0.001	0.00004
AWQS	0.006	0.094 to 0.095	0.0115 to 0.0117	0.0030 to 0.0031	0.00077	0.067 to 0.067	0.005	0.0057 to 0.0059
5	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
25	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
50	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
100	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
200	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
350	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
500	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
1000	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005
2500	0.005	0.0003	0.0007	0.0002	<0.00001	0.002	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Downgradient GW (gpm)	27.5
Downgradient SW (gpm)	80.0
Total Flow (gpm)	151.8

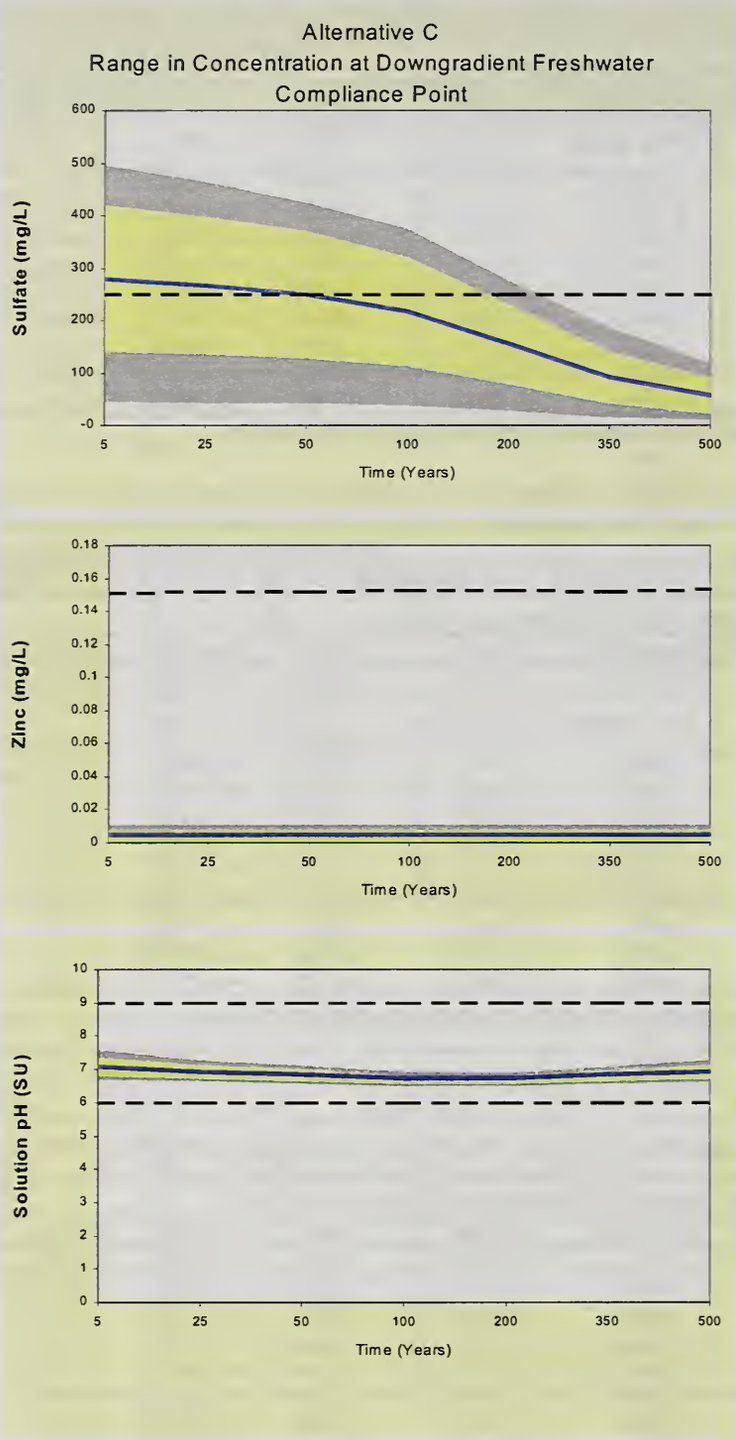
Alternative C - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver
AWQS	NA	NA	0.155	0.405	0.0470	0.410	3.550	0.095
5	0.0125	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
25	0.0125	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
50	0.0125	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
100	0.0125	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
200	0.0125	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
350	0.0124	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
500	0.0123	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
1000	0.0122	0.0004	0.0013	0.0005	<0.00002	0.003	0.001	<0.00005
2500	0.0120	0.0004	0.0013	.0005	<0.00002	0.003	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	15.6
Upwelling GW (gpm)	28.7
Total Flow (gpm)	44.3

Figure 4-7 Alternative C – Range in Concentration at Compliance Point



4.5.4 Alternative D

The expanded area of the tailings pile in this alternative would decrease the tributary area to the three adjacent drainages by approximately an additional 5 percent as compared to Alternative A or approximately an additional 2 percent as compared to Alternatives B or C.

The effects on surface water quality for Alternative D are similar to those of Alternatives B and C, with a greater reduction in surface water flowing into the three adjacent drainages during operations and closure, due to the increased size of the pile.

As with Alternative B and C, this alternative reduces the potential discharge of groundwater with elevated sulfate levels from the bedrock knob in the northwest corner into Cannery Creek or the associated high quality wetlands.

The effects on ground water Alternative D are similar to those of Alternatives B and C. However, due to the increased size of the tailing pile, Alternative D would result in increased groundwater capture by the wet well and treatment system as compared to all other alternatives.

Results from the water quality model for Alternative D are shown in Figure 4-8and Table 4-5. Water quality for Alternative D is similar to that of Alternative B, with concentrations of sulfate and metals slightly higher due to the greater area of the pile. In the underdrain (without dilution, discharge scenario 1(a)), sulfate and antimony may initially exceed AWQS followed by AWQS exceedances of selenium, zinc, and cadmium after 25, 50, and 100 years, respectively.

At the compliance point with dilution (discharge scenario 1(b)), sulfate and antimony initially exceed AWQS, but are predicted to be below AWQS after 200 and 25 years, respectively. Selenium, zinc, and cadmium are predicted to be above AWQS after 25, 200, and 500 years, respectively. These predicted exceedances of AWQS under discharge/compliance scenario 1 would impair existing protected water use classes if discharged without treatment. KGCMC will continue an appropriate method of water treatment until the tailings effluent can be discharged without treatment so that applicable AWQS are met.

Results of the water quality model for Alternative D compared to marine water AWQS (discharge scenario 2) show there are no exceedances.

The predicted load of metals was compared to the loads currently allowable under the NPDES discharge permit using a diffuser in Hawk Inlet. Predicted loads were less than 2 percent of allowable loads for Alternative D for all metals in the permit.

As with Alternatives A and B, effects to water quality in the Hawk Inlet drainage are considered significant for the case where tailings effluent is discharged directly (without treatment) to surface water or groundwater without dilution, or with dilution (without treatment) with surface water or groundwater prior to discharge to receiving waters (discharge/compliance scenario 1). Effects to marine water would be negligible, the same as Alternative A, B, or C for the case where effluent is discharged directly to Hawk Inlet (without treatment or diffuser) (discharge/compliance scenario 2). There would be negligible adverse effects for the case where tailings effluent is discharged through a diffuser into Hawk Inlet (discharge/compliance scenario 3) - the same as under Alternatives A, B, and C. If water treatment were continued in perpetuity, there would be negligible adverse effects to receiving surface water, groundwater, or marine water.

Table 4-5 Alternative D Water Quality Model

Alternative D - Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic freshwater dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS	250			6 to 9	0.050	0.0005 to 0.0006	0.291 to 0.382
5	740	120	7.1	175	0.012	0.0001	0.046
25	744	198	6.9	153	0.011	0.0003	0.240
50	733	274	6.7	128	0.010	0.0006	0.458
100	687	410	6.6	89	0.008	0.0010	0.848
200	518	419	6.6	62	0.006	0.0013	1.118
350	295	280	6.7	62	0.006	0.0013	1.143
500	172	196	6.9	64	0.006	0.0013	1.129
1000	54	121	7.1	73	0.006	0.0013	1.103
2500	32	102	7.2	96	0.006	0.0013	1.092
Tailings Seepage (gpm)		20.8					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		49.5					

Alternative D - Discharge/Compliance Scenario 1(b) Predicted Concentration at Freshwater Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic freshwater dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
Background	6	22	7.1	66	0.005	0.00004	0.0025
AWQS	250			6 to 9	0.050	0.0003 to 0.0006	0.177 to 0.382
5	348	63	7.0	107	0.007	0.0001	0.022
25	349	98	6.9	96	0.007	0.0001	0.103
50	345	133	6.8	83	0.006	0.0002	0.198
100	318	193	6.7	61	0.006	0.0004	0.351
200	243	202	6.7	48	0.005	0.0006	0.480
350	132	139	6.8	48	0.005	0.0006	0.491
500	76	103	6.9	49	0.005	0.0006	0.485
1000	26	66	7.0	54	0.005	0.0006	0.462
2500	17	57	7.1	66	0.005	0.0006	0.455
Downgradient GW (gpm)		27.5					
Downgradient SW (gpm)		95.5					
Total Flow (gpm)		172.5					

Alternative D - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Sulfate	Calcium	pH	Bicarbonate	Arsenic	Cadmium	Zinc
AWQS	NA	NA	6 to 9	NA	1.8	0.4	4.1
5	740	120	7.1	175	0.012	0.0001	0.046
25	744	198	6.9	153	0.011	0.0003	0.240
50	733	274	6.7	128	0.010	0.0006	0.458
100	687	410	6.6	89	0.008	0.0010	0.848
200	518	419	6.6	62	0.006	0.0013	1.118
350	295	280	6.7	62	0.006	0.0013	1.143
500	172	196	6.9	64	0.006	0.0013	1.129
1000	54	121	7.1	73	0.006	0.0013	1.103
2500	32	102	7.2	96	0.006	0.0013	1.092
Tailings Seepage (gpm)		20.8					
Upwelling GW (gpm)		28.7					
Total Flow (gpm)		49.5					

Table 4-5 (continued) Alternative D Water Quality Model

Alternative D - Discharge/Compliance Scenario 1(a) Predicted Concentration in Underdrain Water
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
AWQS	0.006	0.177 to 0.231	0.0222 to 0.0293	0.0078 to 0.0109	0.00077	0.128 to 0.168	0.005	0.022 to 0.037
5	0.015	0.0004	0.0016	0.0006	<0.00003	0.004	0.004	<0.00005
25	0.014	0.0005	0.0016	0.0007	<0.00003	0.006	0.013	<0.00005
50	0.013	0.0005	0.0015	0.0008	<0.00003	0.008	0.024	<0.00005
100	0.010	0.0005	0.0015	0.0008	<0.00003	0.011	0.041	<0.00005
200	0.007	0.0006	0.0014	0.0009	<0.00003	0.013	0.041	<0.00005
350	0.007	0.0006	0.0014	0.0009	<0.00003	0.011	0.024	<0.00005
500	0.007	0.0006	0.0014	0.0009	<0.00003	0.009	0.013	<0.00005
1000	0.007	0.0006	0.0014	0.0009	<0.00003	0.007	0.003	<0.00005
2500	0.007	0.0006	0.0014	0.0009	<0.00003	0.007	0.002	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	20.8
Upwelling GW (gpm)	28.7
Total Flow (gpm)	49.5

Alternative D - Discharge/Compliance Scenario 1(b) Predicted Concentration at Fresh Water Compliance Location
Most probable concentration in diluted underdrain water (mg/L). Constituents that exceed chronic fresh water dissolved Alaska Water Quality Standards (AWQS) are shown in red.

Time	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver (acute)
Background	0.0004	0.0002	0.0002	0.0001	0.000004	0.001	0.001	0.00004
AWQS	0.006	0.109 to 0.231	0.0134 to 0.0293	0.0037 to 0.0109	0.00077	0.078 to 0.168	0.005	0.0078 to 0.0374
5	0.0061	0.0003	0.0008	0.0003	<0.00001	0.002	0.002	<0.00005
25	0.0058	0.0003	0.0008	0.0003	<0.00001	0.003	0.006	<0.00005
50	0.0056	0.0003	0.0008	0.0004	<0.00001	0.004	0.010	<0.00005
100	0.0046	0.0004	0.0008	0.0004	<0.00001	0.006	0.017	<0.00005
200	0.0033	0.0004	0.0007	0.0004	<0.00001	0.006	0.018	<0.00005
350	0.0031	0.0004	0.0007	0.0004	<0.00001	0.006	0.010	<0.00005
500	0.0031	0.0004	0.0007	0.0004	<0.00001	0.005	0.006	<0.00005
1000	0.0031	0.0004	0.0007	0.0004	<0.00001	0.004	0.002	<0.00005
2500	0.0031	0.0004	0.0007	0.0004	<0.00001	0.004	0.001	<0.00005

Data for mercury and silver are below detection in representative contact waters

Downgradient GW (gpm)	27.5
Downgradient SW (gpm)	95.5
Total Flow (gpm)	72.5

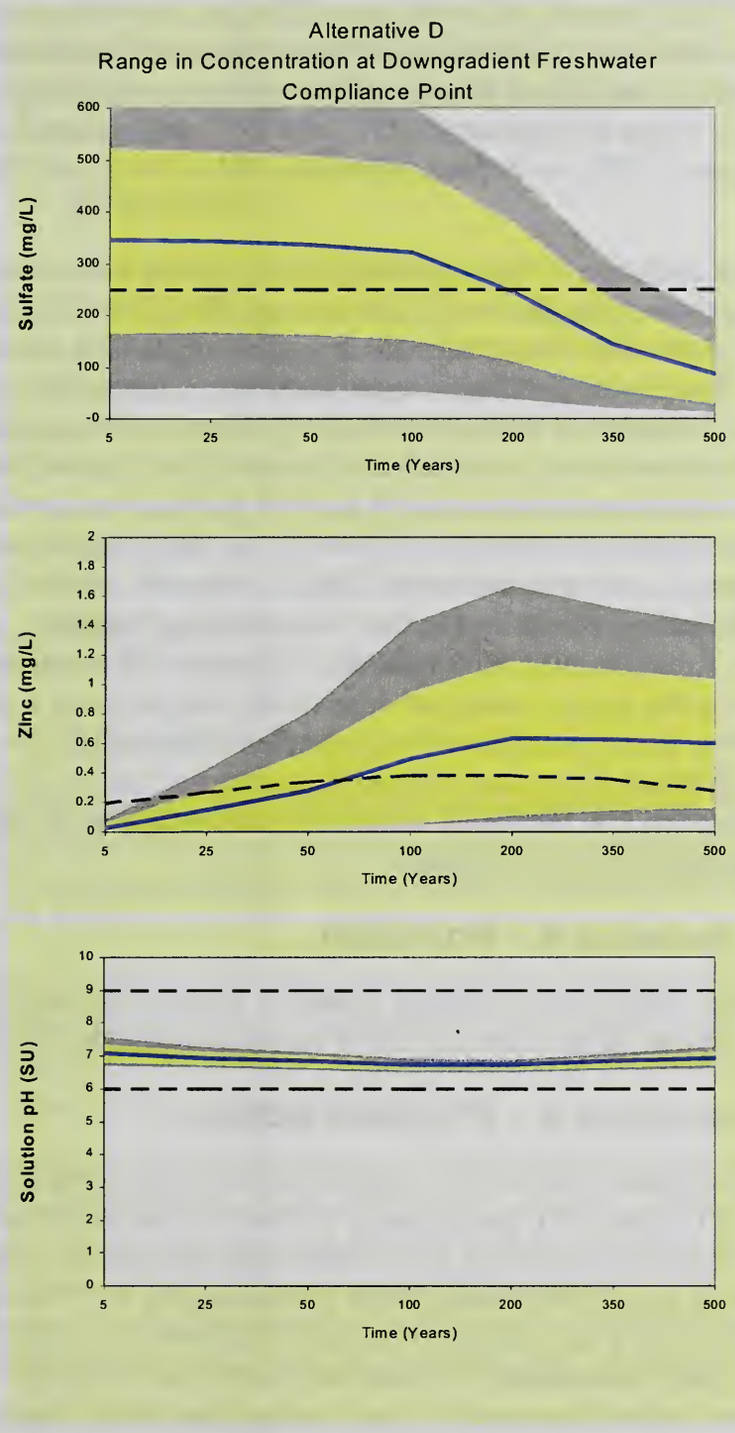
Alternative D - Discharge/Compliance Scenario 2 Predicted Concentration at Marine Discharge
Most probable concentration in underdrain flow (mg/L). Constituents that exceed chronic marine Alaska Water Quality Standards (AWQS) with a 50:1 mixing zone dilution ratio are shown in red.

Time (Years)	Antimony	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver
AWQS	NA	NA	0.155	0.405	0.0470	0.410	3.550	0.095
5	0.0150	0.0004	0.0016	0.0006	<0.00003	0.004	0.004	<0.00005
25	0.0139	0.0005	0.0016	0.0007	<0.00003	0.006	0.013	<0.00005
50	0.0128	0.0005	0.0015	0.0008	<0.00003	0.008	0.024	<0.00005
100	0.0101	0.0005	0.0015	0.0008	<0.00003	0.011	0.041	<0.00005
200	0.0073	0.0006	0.0014	0.0009	<0.00003	0.013	0.041	<0.00005
350	0.0069	0.0006	0.0014	0.0009	<0.00003	0.011	0.024	<0.00005
500	0.0069	0.0006	0.0014	0.0009	<0.00003	0.009	0.013	<0.00005
1000	0.0069	0.0006	0.0014	0.0009	<0.00003	0.007	0.003	<0.00005
2500	0.0069	0.0006	0.0014	0.0009	<0.00003	0.007	0.002	<0.00005

Data for mercury and silver are below detection in representative contact waters

Tailings Seepage (gpm)	20.8
Upwelling GW (gpm)	28.7
Total Flow (gpm)	49.5

Figure 4-8 Alternative D – Range in Concentration at Compliance Point



4.6 Wetlands

This section examines the relative impacts of the alternatives on wetlands and other waters of the United States that fall under the regulatory authority of the Corps of Engineers (COE) and the Environmental Protection Agency (EPA) as defined in Section 404 of the Clean Water Act (CWA).

Permits for the discharge of fill into waters of the United States are approved only through application of the Section 404(b)(1) Guidelines (Guidelines) [see 40 CFR Part 230], which are the substantive criteria for dredged and fill material discharges under the CWA. These areas include jurisdictional wetlands and such other sites as pool and riffle complexes in streams. As discussed under Wetlands in Chapter 3, the Greens Creek project area contains approximately 530 acres of jurisdictional wetlands and a number of streams assumed to fall within the definition of waters of the United States. ...Several individual CWA Section 404 permits have been issued for mining operations in the area, including Tailings Impoundment Area (Permit No. 4-880269). Additional fill in wetlands in connection with this project would be done under this permit or a new permit. In 1994, Three Parameters Plus, completed the analysis on jurisdictional wetland determinations and functions and values. As discussed in Section 3.9, low value wetlands are abundant in the area, especially forested low value wetlands.

4.6.1 Alternative A – No Action

This alternative would have no further impact in wetlands or other special aquatic sites beyond those occurring under currently permitted actions.

4.6.2 Alternative B – Proposed Action

This alternative would result in fill of approximately 22.1 acres of low value wetlands (Figure 4-9). The majority of these wetlands are located immediately downslope (west) of the existing tailings disposal area, with a small inclusion east of the existing mine access road in the "East Ridge" area. Wetlands west of the existing fill consist of forested and short sedge muskeg vegetation associations. The wetland on the East Ridge is forested. These wetlands received a "low" value rating in the functions and values analysis partly because of their proximity to existing disturbance.

In addition, the expanded tailings pile would fill approximately 300 linear feet of high value riparian wetland assumed to be adjacent to a small

stream flowing west from the short sedge wetland, in addition to eliminating the pool and riffle complex of the stream itself. It is assumed by the functions and values analysis that this stream would have adjacent wetlands of three to five feet wide on each bank. Low value wetlands are common in the area.

4.6.3 Alternative C

Alternative C would result in fill or alteration of approximately 10.2 acres of low value wetlands (Figure 4-10). The tailing footprint would of Alternative C and D is shifted to the east compared to the Proposed Action. The expanded tailings pile would fill approximately 100 linear feet of high value riparian wetland assumed to be adjacent to a small stream flowing west from the short sedge wetland, in addition to eliminating the pool and riffle complex of the stream itself. The majority of the wetlands filled would consist of forested vegetation, with a small amount of fill in the short sedge wetland to the west and south of the existing tailings disposal area. This wetland is a part of the same wetland polygon described above for Alternative B.

4.6.4 Alternative D

Alternative D would impact both low and moderate value wetlands. This alternative would result in the fill or alteration of approximately 42.5 acres of low value wetlands, and 0.7 acres of moderate value wetlands (Figure 4-11).

Low value wetlands impacted by this alternative consist of forested and short sedge classifications. The moderate value wetland that would be impacted is a small tall sedge wetland adjacent to the mine access road north of the existing tailings disposal area.

Additionally, as with Alternatives C, the expanded tailings pile would fill approximately 100 linear feet of high value riparian wetland assumed to be adjacent to a small stream flowing west from the short sedge wetland, in addition to eliminating the pool and riffle complex of the stream itself. It is assumed by the functions and values analysis that this stream would have adjacent wetlands of three to five feet wide on each bank.

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Figure 4-8 Alternative B – Wetland Impacts

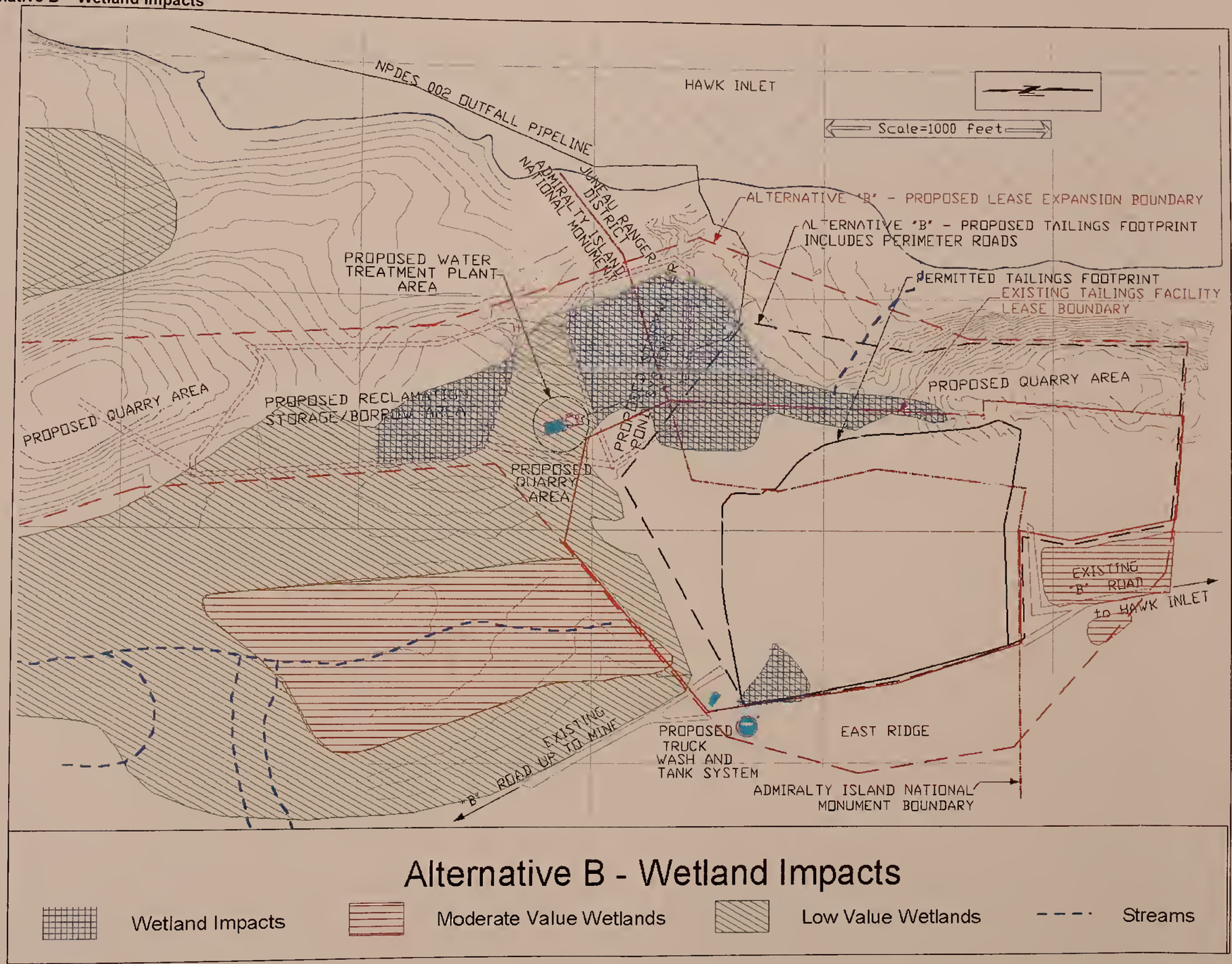


Figure 4-9 Alternative C – Wetland Impacts

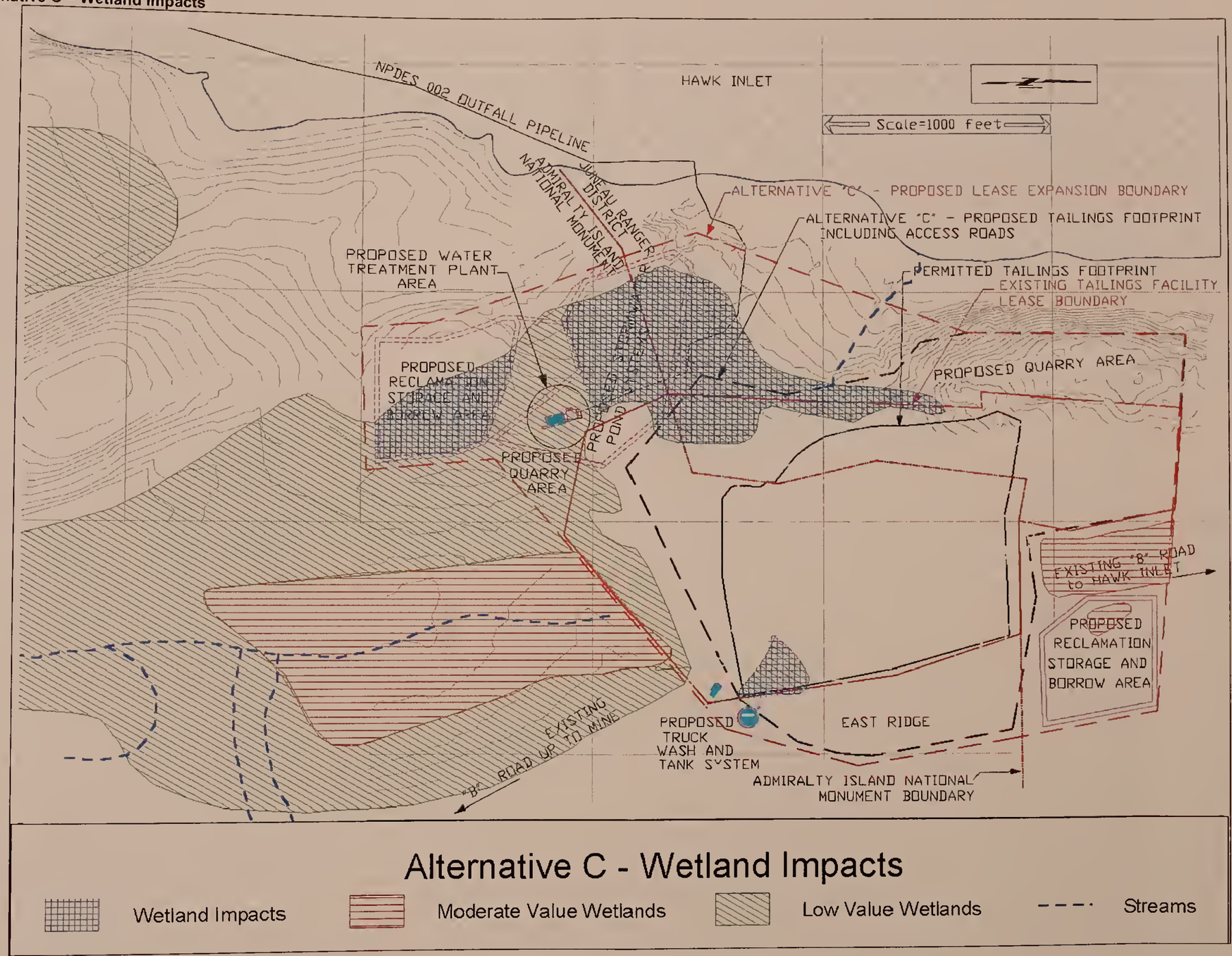
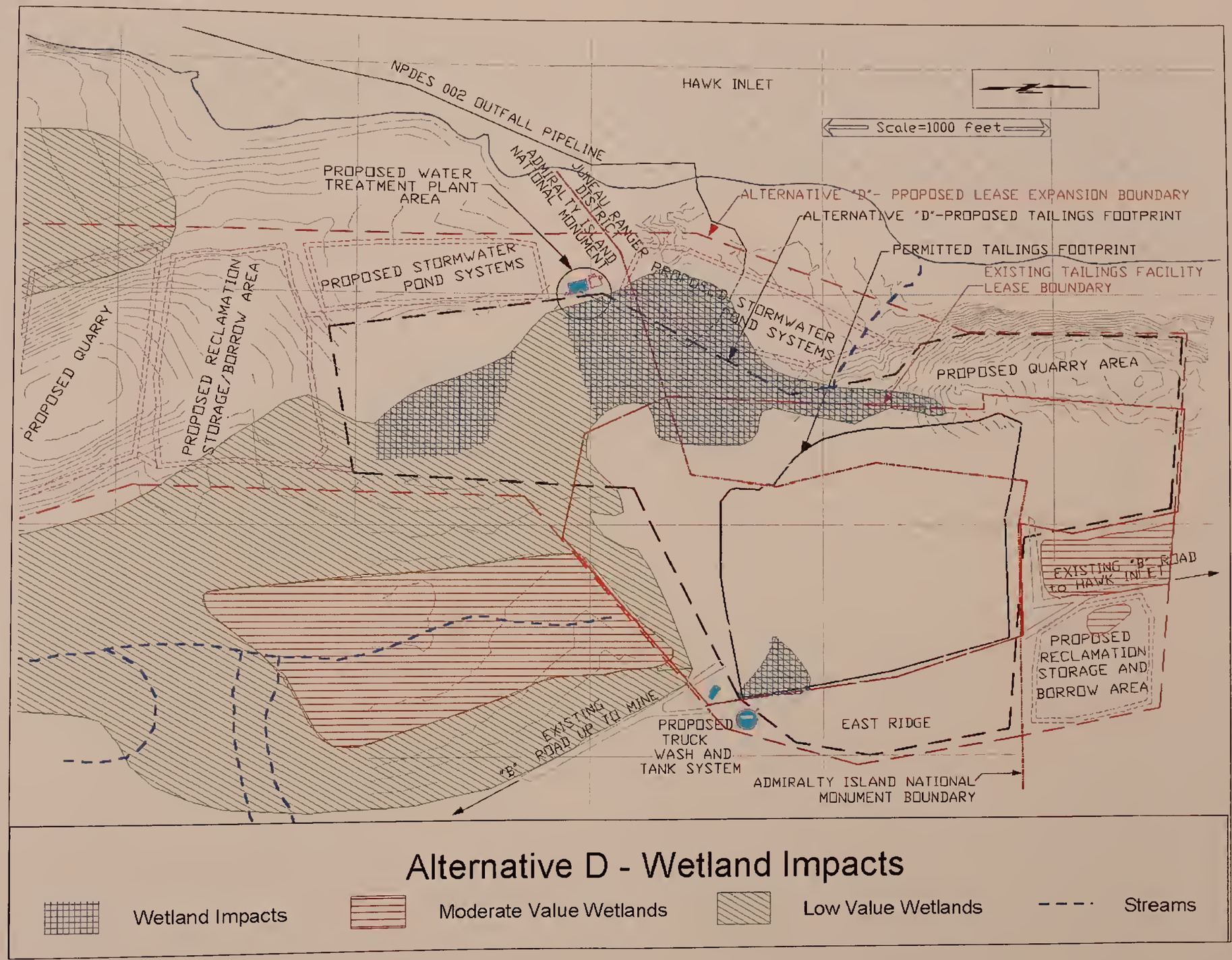


Figure 4-10 Alternative D – Wetland Impacts



4.7 Vegetation

This section describes the impacts to vegetation resulting from the various alternatives discussed in Chapter 2. None of the vegetation loss anticipated under any alternative is considered significant on a project area or regional basis. There are no other projects proposed in the immediate area of the proposed action that would have any effect on vegetation, therefore no cumulative effect on vegetation is anticipated. None of the alternatives would have an indirect effect on vegetation. The vegetation loss anticipated from any of the alternatives is not considered significant either within the project study area or within the region.

4.7.1 Alternative A – No Action

This alternative would have no further impact on natural vegetation beyond that already anticipated under existing permits. The current pile is 23.2 acres and is permitted to increase to 29 acres with related disturbance to total 56 acres.

4.7.2 Alternative B – Proposed Action

This alternative would result in the loss of approximately 71 additional acres of natural vegetation. This vegetation consists primarily of Hemlock and Sitka spruce forest, with a relatively small short sedge muskeg. Most of the vegetated area is rated as upland, with approximately 22.1 acres of the total being low value wetlands (see Figure 4-9).

4.7.3 Alternative C

This alternative would result in the loss of approximately 56 additional acres of primarily Hemlock and Sitka spruce forest. Several small short sedge muskegs would also be impacted. Approximately 10.2 acres is rated as low value wetland (see Figure 4-10). This alternative would disturb the least vegetation of any action alternative.

4.7.4 Alternative D

This alternative would result in the loss of approximately 108 additional acres of Western hemlock and Sitka spruce forest including approximately 42.5 acres of low value forested wetlands (see Figure 4-11). This alternative would disturb the most vegetation.

4.8 Wildlife and Birds

The project will result in an irreversible loss of habitat due to mine tailings piled on the habitat. Under any of the action alternatives (see acreages in Section 4.7, Vegetation above), however, most of the area of the expanded pile footprint has already been cleared as part of the current permitted activities. Over time, some habitat may "come back" when vegetation become re-established on the tailings pile.

Direct habitat losses for mammals will primarily be for small mammals using the habitats. To the extent that larger mammals (brown bears and deer) use the forest fringe adjacent to the pile, they are likely to shift their use. Due to the small amount of acreage affected and the large amounts of unaffected brown bear habitat in the surrounding area, no significant direct, indirect, or cumulative impacts to brown bears are expected. The forested patch that is proposed for the tailings expansion is isolated from other suitable habitats above the existing tailings facility.

Deer have to cross through areas of high activity to access the area, thereby reducing its value to deer. High value deer winter habitats are those areas where crown closure is greater than 95 percent (Hanley, 1998). The current crown closure of the affected forest land is estimated at 70-75 percent. The stand is not connected to any other forested habitat, therefore its value to wintering deer is low in heavy snow years when movements are restricted.

Employees of Greens Creek are not allowed to hunt or fish in the vicinity of Greens Creek so continuation of mine life would not cause pressure from harvesting. Thus, under all four alternatives, the effects on wildlife would continue as they are today, other than the length of time during which the mine would continue to operate. Once the mine shuts down, this habitat will gradually be restored, but harvesting pressure may increase with people hunting where they are not currently allowed.

Under Alternative A, the mine would close in 2 years. Under Alternatives B and C, the mine would probably have a remaining life of 22 years. Under Alternative D, there would be tailings storage capacity for 22 years, but it is probable the increased costs would result in closure before all tailings capacity was used.

The Standards and Guidelines for Wildlife (Chapter 4, Page 4-110 http://www.fs.fed.us/r10/TLMP/F_PLAN/FPTOC.PDF) established in the 1997 Forest Plan is included in the Planning Record. The Standards and Guidelines for Sitka black-tailed deer, bald eagles, brown bear, American marten, and marbled murrelet would be complied with under any of the alternatives.

Research has documented that responses of birds to timber harvest are mixed and highly species specific. All of the alternatives that propose to expand the existing tailings facility into the mature forest habitats. Nest sites will be lost in the areas that are cleared. Changes in forest structure will positively affect some bird species and negatively affect other species. In most instances, over time, forests that have been harvested, or disturbed by factors such as blowdown or fire, will grow back and complex stand structure will develop again on the site.

Four alternatives have been developed in the Final Environmental Impact Statement. All alternatives, except the No Action alternative, propose to enlarge the existing tailings pile and remove some mature spruce/hemlock forest. Other habitats (ex. alpine, muskeg, riparian) in the area will not be affected.

Table 3-12 lists all of the priority species that are known to occur in mature/old-growth Spruce-Hemlock habitats on the Tongass National Forest. These species were selected because the proposed expansion of the existing tailings pile will affect a stand of spruce/hemlock forest habitat adjacent to the existing tailings storage facility. Other habitats (ex. shoreline, beach and estuary fringe etc.) will not be affected. Table 4-6 displays the number of acres of spruce/hemlock habitat that will be affected under each alternative.

Table 4-6 Acres of Spruce/Hemlock Habitat Affected Under Each Alternative

Alternative	A	B	C	D
Acres	29*	71	56	108
* The existing tailings pile is 23.2 ac. It is currently permitted to expand to 29 acres.				

The primary effect to birds would be nest destruction or abandonment if the activities occur during the breeding/nesting period. Nesting in Southeast Alaska generally begins in May. By September, the young birds have fledged and they would not be directly affected (pers. comm. Gwen Baluss, Tongass National Forest, Juneau Ranger District). A stipulation that all tree removal activities related to the expansion should include direction that tree harvest occur only between September through April. This measure would eliminate adverse effects to nesting neotropical migrants and resident bird species.

The forested habitat that would be lost as a result of the tailings expansion storage area does not have the structural attributes that are preferred for murrelet nesting sites. It is unlikely that marbled murrelets use the area. Dawn watch surveys should be conducted prior to the commencement of any disturbance activities. Kittlitz's murrelets forage almost exclusively at the face of tidewater glaciers or near the outflow of glacial streams, and

nest in alpine areas in bare patches among the ice and snow. Neither foraging nor nesting habitat for the Kittlitz's murrelet are in the area of the Greens Creek Mine.

4.9 Marine Mammals

Six, non-T&E, marine mammal species occur in or near Hawk Inlet: harbor seal, killer whale, harbor porpoise, and Dall's porpoise.

As discussed in Chapter 3, Section 3.11.6 harbor seals, killer whales, harbor porpoise, and Dall's porpoise are seen in Hawk Inlet at irregular intervals. Gray whales and minke whales occur in Chatham Strait, but have not been observed in Hawk Inlet. There are no activities associated with any of the proposed actions, including associated traffic from ore barges or ships that would be expected to adversely affect any of these species. No activity associated with any of the alternatives would constitute harassment or a taking under Marine Mammal Protection Act.

4.10 Threatened and Endangered and Alaska Region Sensitive Species

A Biological Evaluation (BE) for Sensitive Species of Plants was conducted. No sensitive plants were found. The proposed action is not expected to have any indirect or cumulative effects on sensitive plants (Dillman, 2003).

A BE has been completed (Rickards, 2003) to assess the affects of the proposed activities on federally listed Threatened and Endangered fish and wildlife species. The BE determined that there will be no adverse impact to these species. The Threatened and Endangered fish species that are listed for the Tongass National forest are found in the marine waters on the outside coast, to the west of the Tongass National Forest. Federally listed mammals include the humpback whale and Steller sea lion. Critical habitat has not been designated for the humpback whale. Critical habitat for the Steller sea lion will not be affected. No provision of any of the alternatives would constitute harassment or a taking under the Endangered Species Act.

Northern sea otters (a candidate species for T&E status) generally occupy "outside" waters of the Southeast Alaska panhandle and are rarely seen inside, or east of Icy Strait. There have been only two confirmed sightings of sea otters within Chatham Strait in the past ten years. If sea otters were to extend their range into Hawk Inlet, there are no activities proposed in any alternative that would adversely impact them.

Both Steller sea lion and humpback whales occasionally visit Hawk Inlet. Risks to these higher trophic level mammals could occur primarily through transfer of metals from prey items. Risks to humpback whale and sea lion, are not likely, due to the transient nature of these species in Hawk Inlet, (OIO and RTI, 1998).

Similarly to northern sea otters, if either species were to spend more time in the Inlet, neither would be adversely affected by activities associated with any of the proposed actions, including associated traffic from ore barges or ships. No activity associated with any of the alternatives would constitute harassment or a taking under the Endangered Species Act or the Marine Mammal Protection Act.

4.11 Marine and Aquatic Habitats, Biota, and Essential Fish Habitat

The potential effects of all alternatives relative to the tailings facility and contact water discharge into Hawk Inlet are discussed here. Other impacts of mining activities on marine and freshwater habitats (e.g. ship loading, fuel spill risks, etc.) are discussed under the cumulative impacts (Section 4.17.5).

Under Alternative A, the mine would close in 2 years. Under Alternatives B and C, the mine would probably have a remaining life of 22 years and, under Alternative D would probably be somewhat less than 22 years.

Under all alternatives, all contact water is contained, collected and treated prior to marine discharge; therefore there is no drainage to freshwater EFH nor impact from metals, pH, or other contaminants. Watershed impacts of the different alternatives differ by acreage of wetlands filled. Alternative A would not result in wetland fill that has not already been permitted. Alternative B would result in filling 22.1 additional acres of low value wetlands, Alternate C, 10.2 acres of low value wetlands, and Alternative D in the fill of 42.5 acres of low value wetlands and 0.7 of medium value wetlands (See Section 4.6). Despite these differences, the watershed impacts to EFH of all alternatives are considered negligible.

No direct or indirect structural impacts to marine EFH are anticipated under any of the alternatives. Under all alternatives, all contact water will meet NPDES limits and/ or AWQS, whether discharged to a marine mixing zone, a marine outfall without mixing zone, or a surface or groundwater discharge (See Section 2.2 Elements Common to All Alternatives). All alternatives involve continued flow of effluent at outfall 002 into Hawk Inlet unless a surface or groundwater discharge

point, which meets the NPDES and AWQS standards, is used post-closure.

The only direct effect on marine habitats anticipated resulting from the action alternatives would continue to be input of submarine freshwater plumes from outfall 002. Mobile fish and shellfish will likely avoid the freshwater, resulting in negligible disturbance. Passive pelagic forms such as larval crustaceans, plankton and dinoflagellates will not likely be able to avoid the freshwater plume, and may experience mild osmotic stress. However, because of the typically strong salinity-defined boundary between saltwater and such a freshwater input, it is not likely that marine plankton will be affected by effluent plumes to a significant degree. No other direct impacts to marine habitat, fish or shellfish in Hawk Inlet are anticipated under any of the action alternatives.

There has been increases in some metals in marine sediments which have increased at Station S-1 since the installation of outfall 002. These include Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg), Selenium (Se) and Silver (Ag). In marine worms, Chromium (Cr), Pb and Nickel (Ni) average levels increased at Stations S-1, S-2, S-3 and As, Cr, Copper (Cu), Pb, and Ni increased at S-1. Under all alternatives, metal levels in sediments near the outfall is predicted to increase, with levels for As, Cr, Cu, and Zn in exceedance of National Status and Trends, Effects Range – Low, and Ni in exceedance of Effects Range – Median.

Under all alternatives, it is anticipated that Cr, Pb and Ni would continue to increase in marine worm tissues throughout Hawk Inlet. Additionally, As and Cu are predicted to increase in marine worms near the outfall.

Based on mussel data presented in Chapter 3, it is likely that Cr, Cu, Pb and Ni may continue to increase in concentration in mussel tissue under the proposed alternatives. As and Hg may also increase in mussel tissue. All metals in mussels are within the range for Alaska Mussel Watch data, except Cd, which was elevated prior to mining activity.

Determining risk to higher trophic level organisms, based solely on sediment and invertebrate tissue concentrations, is highly uncertain. Determining food chain effects should include: 1) knowledge of the local habitat use; 2) dietary composition of prey items for a range of secondary and tertiary trophic species; 3) known or estimated trace metal accumulation levels within these prey, and 4) confirmation of trophic transfer through measuring metal body burdens in fish, mammals or avian species.

Risks to higher trophic level beings such as fish, shellfish, mammals and birds could occur primarily through transfer of metals from prey items.

Species with EFH likely to be most susceptible to metal intake through feeding include bottom feeders such as skates, rays, flatfish, pacific cod, and crab and their prey. Risk to higher trophic organism such as whale, seal and sea lion, is not likely, due to the transient nature of these mammals in Hawk Inlet.

Habitat areas of particular concern

HAPCs in Hawk Inlet include canopy kelp beds, eelgrass beds and mussel beds. None of the alternatives are expected to adversely affect the physical structure of these habitats. Kelps typically concentrate heavy metals from ambient seawater. It is not known whether, or to what degree, heavy metals bound in kelp tissues would be biologically available to herbivores grazing on the kelps such as sea urchins and snails. Eelgrass beds in Hawk inlet are not expected to be affected by any of the action alternatives. Mussel beds will likely continue to concentrate heavy metals, as described above.

Mitigation Measures

The Magnuson-Stevens Act calls for inclusion of measures to minimize or avoid adverse impacts to Essential Fish Habitat to the extent practicable in all activities which may adversely affect waters required by fish for breeding, rearing, spawning or growth to maturity. The Forest Service has determined that the Greens Creek mining activities may adversely affect the Essential Fish Habitat. A broad suite of measures crafted to protect elements of the Hawk Inlet environment and adjacent watersheds from mining activities have been integrated into the design and construction plans under each of the action alternatives. These design elements are discussed in Section 2.2, Elements Common to all alternatives.

In addition to these measures, NMFS has made the following conservation recommendations to characterize, minimize, and avoid adverse effects on EFH in Hawk Inlet.

1) Collect multiple samples for each site for both tissue and sediment to reduce sampling bias and capture contaminants that are distributed in patches.
2) Collect grain size information for sediment samples at all sampling sites.
3) Conduct surveys for seafloor community structure – abundance and diversity

4) Sample resident fish tissues for heavy metals to determine whether metals are bioaccumulating or biomagnifying in Hawk Inlet food webs.

5) Develop a remediation plan for addressing contaminated sediments at ore ship loading dock.

The Forest Service has consulted with NMFS, the EPA, as well as the ADEC regarding EFH and NMFS' conservation recommendations. Recommendations # 1 - 4 above fall under the jurisdictional authority of the EPA and will be integrated into the NPDES permit which will be reissued in November of 2003. The 5th NMFS recommendation to develop a remediation plan for addressing contaminated sediments at the ore ship loading facility will be addressed in the Greens Creek Mine GPO. Currently, KCGMC is working in cooperation with NMFS, the EPA, and the ADEC to develop a comprehensive monitoring plan that will integrate all 5 of the NMFS recommendations above, including recommendation #5, the remediation plan. This comprehensive monitoring plan will become part of the Greens Creek Mine GPO.

Summary of Impacts to Marine and Aquatic Environment

Based upon data provided in this document and supporting documents, all alternatives for the Greens Creek Mine Tailings expansion are predicted to have minor impacts on marine EFH due to metals accumulation. Negligible impacts to anadromous EFH are predicted for all alternatives. None of the alternatives are expected to adversely affect managed species' populations. The anticipated degree of impact by alternative on features of the Hawk Inlet ecosystem are summarized in Table 4-7below.

Table 4-7 Summary of Effects to Marine and Aquatic Ecosystems

Alternative	Marine Habitats	Marine Biota	Aquatic Habitats	Aquatic Biota	EFH
ALT A	Minor	Minor	Negligible	Negligible	Minor
ALT B	Minor	Minor	Negligible	Negligible	Minor
ALT C	Minor	Minor	Negligible	Negligible	Minor
ALT D	Minor	Minor	Negligible	Negligible	Minor

4.12 Heritage Resources

The heritage resource review of this project has resulted in a determination of "No Historic Properties Affected" from direct, indirect, or cumulative sources. Alternative A presents the least potential for impacting a yet unknown heritage resource. This is because under the no

action alternative, the least amount of acreage would be disturbed, and activities that could potential disturb an unknown site would be limited to the probable life of the mine of approximately two years. This is compared to the other alternatives, under which activities with the potential to disturb an unknown site would continue for approximately 22 years.

Alternative C presents the next smallest potential risk to heritage resources. The additional lease area for Alternative C (67.3 acres) is the smallest among the action alternatives, and as such, it would be expected to have the least potential for adverse effects.

The 84.5 acre expansion considered under Alternative B would present a greater risk than that presented by Alternative C. Alternative D, with the largest expansion (116 acres), would present the greatest potential risk to heritage resources.

The risk to a potential heritage resource site or artifact that might be on the project site is twofold. A site or artifact could be dug up during excavation and damaged in the process, or it could be covered with tailings. These risks increase proportionately with the amount of disturbed acreage for each alternative. On the other hand, the chance of such an artifact being found, properly preserved, and repatriated also increase with the amount of disturbed acreage.

4.13 Subsistence

The analysis of effects on subsistence is similar to the analysis under Wildlife in Section 4.8. As described in Chapter 3, the reliance on subsistence resources in this area is minor. As described in the Wildlife section, each of the alternatives would have negligible effects on fish and wildlife resources. Therefore, none of the alternatives would decrease the quality, abundance or availability of subsistence resources. None of the alternatives would impact subsistence users' access to fish or wildlife resources. Metals contamination could impact the edibility of shellfish from Hawk Inlet, but use of this resource appears to be minimal. For all these reasons, the impacts of the project are deemed negligible to subsistence use of wildlife, fish, or other foods.

4.14 Recreation

Each alternative would have negligible impact on recreation. Existing tourism to Angoon, which centers on fishing, big game guiding, camping, bear watching, and canoeing, would be expected to continue with

minimal, if any, impacts from any of the alternatives. The same is true for sightseeing and fishing tours centered on Admiralty Creek and Oliver Inlet, on the western side of Admiralty Island.

4.15 Socioeconomic

Socioeconomic effects of the four alternatives depend on the life of the mine anticipated under each alternative. Socioeconomic effects are measured in terms of prolonged or additional economic benefits.

While Greens Creek currently has enough tailings disposal capacity for approximately two years of operation, the mine has proven reserves that indicate a remaining life of 12 years and reasonably foreseeable discoverable reserves for another 10 years (20 years past closure under the No Action alternative). Alternative A, the no action alternative, would result in closure of the mine after about two years. Alternatives B, C, and D would each provide enough tailings disposal area to meet the mine's needs for its remaining 12-years of proven reserves and 10 additional years of reasonably foreseeable expected discoveries. The socioeconomic effects, measured as prolonged benefits, could include (for example) annual direct payroll of $26 million (ADOL, 1999). If a particular alternative increases the mine's life by twenty years (twenty years beyond that currently anticipated), the economic effect would include $520 million in total additional payroll to the mine's employees.

The socioeconomic impacts of mine closure are, in absolute terms, the same for each alternative. When the mine closes, Juneau's economy will lose the benefit of the direct employment and payroll, in addition to the indirect and induced employment and payroll generated through the consumption of local goods and services by mine employees and their dependents. These impacts are summarized in Table 4-8.

Table 4-8 Socioeconomic Annual Summary

	Direct	Indirect	Total
Employment	265	141	407
Payroll	$26,000,000	$11,960,000	$37,960,000
Population	409	217	626
School Enrollment	82	43	125
Housing	152	80	232

Employment and payroll multipliers were developed from the Impact Analysis for Planning (IMPLAN) model, which produces an employment multiplier of 1.53 and a payroll multiplier of 1.46. It is important to note

that these multipliers are not based on rigorous assessment of the mine's role in Juneau's economy. Population estimates are based on a participation rate of 0.65. The number of school age children in the mine-related population is based on an estimated ratio of one school age child for every five residents. This estimate is based on an analysis of school enrollment data and population data (CBJ, 2003) (ADOL, 1991-2000). Housing estimates are based on an average household size of 2.7, as measured in the 2000 census.

The impact of mine closure also includes loss of property tax revenues to the City and Borough of Juneau. In 2001, Greens Creek paid $672,000 in property taxes (CBJ, 2002). If the mine is forced to close because of loss of tailings disposal capacity, the value of the mine is reduced to its salvage value—a fraction of its value with adequate tailings disposal capacity.

In addition to the timing of the mine closure, the impacts of alternatives also differ in the relative impact on the economy. Juneau's economy is expected to grow slowly through 2018, at an annual rate of about 0.6 percent, according to Alaska Department of Labor and Workforce Development projections.[5] Therefore, mine closure in the near-future would have a slightly greater relative impact in Juneau than mine closure in the more distant future. Two years from now, Juneau's population would be about 2 percent above the current level. In 12 years, Juneau population would be about 9 percent above today's level. Though the difference is relatively small, this suggests that Juneau's economy could better absorb the economic impacts of mine closure in the more distant future.

Alternative A – No Action

Alternative A provides tailings disposal capacity for only two years of operations. In two years, closure of the Greens Creek Mine would represent a loss of 2 percent of Juneau's population base, assuming an annual growth rate of 0.6 percent through 2005 and all mine employees left Juneau.

On an economic basis, this alternative represents worst case of all alternatives for KGCMC as it eliminates the revenue stream, which removes any value associated with continued production at the mine. Implementation of Alternative A would result in early mine closure, lose

5. Alaska Department of Labor and Workforce Development, Research and Analysis Section, Demographics Unit.

of jobs and support services, thus resulting in the worst economic scenario for KGCMC and the families it employs.

Alternative B – Proposed Action

This alternative provides tailings disposal capacity for 12 more years of operations—ten years more than under the no action alternative. This alternative would result in $520 million in additional direct payroll and $239.2 million in additional indirect payroll. In total, by prolonging the life of the mine by twenty years, an additional $759.2 million in payroll would be created. In addition, the City and Borough of Juneau would receive several million dollars in additional property taxes under Alternative B.

Closure of the Greens Creek Mine in 12 years would represent a loss of 1.9 percent of Juneau's population base, assuming an annual growth rate of 0.6 percent through 2015 and all mine employees left Juneau.

Alternative B and Alternative C are similar in capital cost, as they represent the same relative footprint expansion for the tailings pile. Full build out for development, construction and reclamation costs will be similar for both these options and could range between $10,000,000 - $20,000,000. Operating costs for Alternative C will have additional costs associated with the SRMP Program and research to develop a carbon amendment if necessary, adding cost in the potential range of $1 - 6,000,000 over Alternative B.

Alternative C

The socioeconomic effects under Alternative C are the same as those described under Alternative B and all mine employees left Juneau.

Alternative B and Alternative C are similar in capital cost, as they represent the same relative footprint expansion for the tailings pile. Full build out for development, construction and reclamation costs will be similar for both these options and could range between $10,000,000 - $20,000,000. Operating costs for Alternative C will have additional costs associated with the SRMP Program and research to develop a carbon amendment if necessary, adding cost in the potential range of $1 - 6,000,000 over Alternative B.

Alternative D

Alternative D represents a high economic burden for KGCMC, because of the requirement for an addition of 2.5 million tons of carbonate material to the tailings pile. The increase in acreage needed to place this material

raises all capital cost totals by approximately 150% ($15 - 30,000,000) simply to develop, construct and reclaim the full build out as described in the environmental analysis over the Alternatives B or C. Also, operating costs are extremely high, because the material needed would consist of an imported (off-island source) product. KGCMC currently imports pebbled lime products that would be suitable to add to the pile to satisfy the Alternative D requirement at approximately $100/ton. This represents a $250,000,000 increase in operating costs, and most likely an uneconomic future for the mine resulting in mine closure. If a suitable material option could be found at even 25% of the current lime costs (roughly our costs for rock road), increased operating costs would still increase by over $60,000,000. This amount also challenges the economic viability of the operation and would probably result in early mine closure.

To the extent that this alternative adds twenty years to the mine's life, the socioeconomic effects are the same as Alternative B. However, Alternative D involves substantially higher costs than the other action alternatives ($133 million to implement Alternative D, as opposed to $30 million to implement either Alternative B or C). As such, implementation of Alternative D would have a much greater affect on mine cash flow and profitability than would implementation of the other action alternatives. The increased operating costs associated with Alternative D would make the mine more susceptible to price fluctuations and place it at greater risk for temporary or longer-term shutdown if metals prices were to decline. Furthermore, higher operating costs generally result in higher cut-off grades. With higher cut-off grades, less of the available ore can be mined at a profit. The combination of these factors could be anticipated to result in reduced profitability that would shorten the life of the mine.

4.16 Environmental Justice

Executive Order (EO) 12898 *(Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*), requires that Federal agencies identify and address disproportionately high and adverse human health and environmental effects of its actions on minority and low-income populations.

Topics specified in Executive Order 12898 are addressed under Affected Environment (Chapter 3) and Environmental Effects (Chapter 4) in this EIS. Chapter 3 describes the socioeconomic characteristics of the nearest community, including ethnic composition of the population, employment, income levels and subsistence activities.

Chapter 4 describes the environmental consequences of the project alternatives on: fish and wildlife used by local residents for subsistence,

subsistence activities and harvest levels, heritage and archaeological resources, employment opportunities and improved transportation.

The Greens Creek project is not close to any community. There are recreational cabins at Wheeler Creek – approximately 5 miles away and Funter Bay - approximately 10 miles away. Greens Creek is in the City and Borough of Juneau, but is approximately 15 miles from its populated portions. The nearest minority communities are Hoonah (28 miles) and Angoon (44 miles).

Because none of the alternatives would have disproportionately high and adverse human health and environmental effects in general, or specifically on minority and low-income populations., and because Greens Creek specifically directs training programs and employment opportunities to residents of Angoon, alternatives which offer an extended mine life (Alternatives B, C, and D) offer minor positive environmental justice impacts.

4.17 Cumulative Impacts

4.17.1 Cumulative Impact Definition and Impact Analysis

"Cumulative impact" is the impact on the environment that results from the incremental impact of the actions when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).

The Greens Creek mine and its tailings pile already exist. The No Action alternative considered in this document represents a continuation of the existing mining operation for approximately 2 more years. All action alternatives represent an extension of mining operations of approximately 20 more years, 10 years based on known reserves and a probable additional 10 years beyond based on reasonably foreseeable discoverable reserves. Consequently all analyses of impacts throughout this chapter consider the impact of the mine operation in the past, combined with the anticipated impacts of future operations.

Past, present, and reasonably foreseeable future impacts included in these analyses are not limited to tailings disposal impacts. Rather, these analyses include consideration of available data and information (such as fresh water monitoring data, management and reclamation plans, and other mitigation measures) on impacts of all mine activities affecting the

same environmental resources as the alternatives considered in this document. Such activities include facility construction as well as use and disposition of production rock.

All analyses also consider impacts or mitigation of impacts under the Reclamation Plan (Appendix 14 to the KGCM General Plan of Operations contained in Appendix C – Selected Appendices from the KGCM General Plan of Operations) as well as under the section pertaining to management of production rock piles (Appendix 11 to the KGCM General Plan of Operations).

Overall, there would be very small differences between any of the action alternatives in terms of cumulative effects. These small differences are greatly overshadowed by the inherent uncertainty in making estimates of past, present, and reasonably foreseeable cumulative effects. Therefore, we present just one analysis for all three action alternatives. No significant cumulative impacts are expected to result from any of the planned activities associated with any of the alternatives.

4.17.2 Scope of Analysis

To keep the cumulative-effects analysis useful, manageable, and concentrated on the effects that are meaningful, greater weight has been given to activities that are more certain and geographically close to the project with a focus on issues of greatest concern. The scope for the analysis of cumulative impacts used in this EIS is:

- Identify potential effects of the expansion of the tailings pile and attendant extended life of the Greens Creek mine that may occur on the natural resources and human environment. (See Chapter 4.)
- Analyze other past, present, and reasonably foreseeable future projects that reasonably could affect the natural resources in the vicinity of the Greens Creek mine.
- Attempt to quantify effects by estimating the extent of changes to existing environment (Chapter 3).
- Consider the guiding principles from existing standards, criteria, and policies that control the management of the natural resources of concern.

Spatial and Temporal Boundaries of Analysis

The analysis of impacts to different resources has involved the use of different spatial boundaries. For example in analyzing the impacts on

visual quality, it makes sense to analyze impacts within visual range of the project or other portions of the mine. In analyzing socio-economic impacts, the boundaries of the analysis are expanded to the effect of the continued life of the mine on the economy of the City and Borough of Juneau.

Likewise, the analysis of impacts to different resources has involved the use of different temporal boundaries. Impacts to wildlife from the human activity associated with the operation of the mine or reclamation activities can be measured in a shorter time frame (probably less than 30 years. Analysis of the potential effects on the pile on water quality and secondary impacts on fish, wildlife, and vegetation demand a much longer time frame. In the stochastic model used to predict water quality we have used a time frame of 500 years (as a point of reference Columbus landed in the Americas 505 years ago).

4.17.3 Guiding Principles from Existing Standards, Criteria, and Policies that Control the Management of Natural Resources of Concern

The Greens Creek mine is in the Tongass National Forest. The use of the land for the mine is consistent with the Tongass Land Management Plan. The State owns the tidelands in Hawk Inlet. It does not have specific plans that apply to the mine. The mine is in compliance with the state's general policies that apply to use of tidelands and to mines. Because there are no T & E species within the project area it is not affected by the Endangered Species Act.

The Greens Creek mine is within the City and Borough of Juneau. The use of the land for the mine is consistent with Juneau's Comprehensive Land Use plan. The City and Borough of Juneau Coastal Management Program contains enforceable policies that govern general land use in coastal areas (CBJ, 1992). All land and water use activities are to be conducted with appropriate planning, implementation and monitoring/enforcement to mitigate potentially adverse effects and/or cumulative impacts on: fish and wildlife population and their habitats, commercial fishing uses and activities, subsistence and personal use resources and activities, air and water quality, heritage resources and recreational resources.

The ACMP set forth mitigation as follows:

- Avoid.
- If not avoidable minimize loss by limiting the degree of magnitude or the action and its implementation.

- When loss of resources and/or associated activities of local, state or national importance cannot be minimized, restore or rehabilitate the resource to its pre-disturbance condition to the extent feasible and prudent.

When loss of important habitat or activities of local, state, or national importance is substantial and irreversible and cannot be avoided, minimized or rectified, compensate for the loss by replacing, enhancing, or providing substitute resources or environments. Compensation may be in-kind or out-of-kind, and off-site or on site. The preferred options are in-kind and on-site, to the extent feasible and prudent.

The Marine Mammal Protection Act of 1972 established a moratorium, with certain exceptions, on the taking of marine mammals in U.S. waters. Nothing under any of the alternatives considered in this EIS would result in the "take" or "harassment" of any marine mammal.

4.17.4 Reasonably Foreseeable Future Cumulative Impacts

The continued operation of Greens Creek mine would continue to have positive cumulative socioeconomic impacts on the City and Borough of Juneau. AEL&P has been interested for some years in running an electric line from Douglas Island, under Stephens Passage, to the Greens Creek Mine. An extension of the projected mine life would increase the possibility of such an extension. If AEL&P participated in a Southeast Intertie, it is also possible that such a line might be done as part of that effort.

The Forest Service Tongass home page (http://www.fs.fed.us/r10/tongass) and the Tongass Land Management Plan, as well as the web sites of the Alaska Department of Transportation and Public Facilities (http://www.dot.state.ak.us), the Alaska Department of Community and Economic Development (DECD) (www.state.ak.us/dced/commdb./CF-RAPIDS.cfm), and the City and Borough of Juneau (http://www.juneau.lib.ak.us/) were reviewed for potential projects in the area of the Greens Creek mine. No existing partially funded, or potential projects were found for the area of the Greens Creek Mine.

The main source of cumulative impacts for the tailings pile expansion is the continued operation of the mine, and its associated facilities such as the mill, roads, offices, Young Bay dock, and Hawk Inlet seaplane and barge loading docks. The effects of this continuation are discussed resource by resource.

4.17.5 Cumulative Effects by Resource

As discussed at the beginning of this section, because all alternatives are based on the continuation of an existing project, all analyses of impacts throughout this chapter evaluates the cumulative effect on the existing environment from past, present, and reasonably foreseeable future actions on each relevant resource in the Greens Creek mine area. The analysis of impacts on monument values, air quality, visual quality, hydrology, wetlands, vegetation, wildlife, threatened, endangered species, essential fish habitat, heritage resources, subsistence, recreation, and socioeconomics include the cumulative effects of past mining operations. There are no reasonably foreseeable future actions other than the proposed project itself that will impact any of these resources.

Land

Section 503 of ANILCA provides that, "with respect to the mineral deposits at Greens Creek. the holders of valid mining claims … shall be entitled to a lease (and necessary associated permits) on lands under the Secretary's Jurisdiction …. for use for mining or milling purposes … from such claims situated within the Monuments," provided "that the use of the site to be leased will not cause irreparable harm to the … Admiralty Island National Monument and … the Secretary shall limit the size of the area covered by such lease …"

Alternative C would lease the least additional acres with the Monument of any of the action alternatives (Additional lease acres in the Monument Alternative B 52 acres, Alternative C 30 acres, and Alternative D 67 acres).

No additional acres for the mine site, mill site, or roads are expected to be disturbed and add to cumulative impacts to Monument Values. No irreparable harm is predicted to occur to the Monument because of the combined effect of the tailing and other mine components over the extended life of the mine.

Air Quality

The direct, indirect, and cumulative are expected to be negligible for the life of the mine and none after closure.

Visual Resources

There are no visual impacts expected in the vicinity of the Greens Creek mine, other than mine related activities. The tailing pile is the most visible feature of the Greens Creek mine. The other components of the

mine are only visible when within their immediate vicinity. The reclamation plan for all alternatives would comply with Appendix 14 of the October 2000 GPO and with the DEC Waste Management Permit. Under all alternatives, the capped pile would have slopes of approximately 3 to 1. This is steeper than the muskegs and forested slopes between the pile and Hawk Inlet, but is not as steep as some of the forested slopes directly above the location of the finished pile. Overall, the topography of the pile will blend into the hummocks and slopes of the surrounding area. All alternatives are consistent with The Forest Plan for the Non-Wilderness National Monument LUD VQO of Maximum Modification. Considering mitigation measures and timing, impacts to the scenic quality would be consistent with the Visual Quality Objectives for the assigned LUD Prescriptions. Approximately 40 years after mining operations have ceased, the site would meet the VQO of Retention.

Surface Water Hydrology

Impacts to surface water quality in the three receiving drainages will be minor during the operations and closure phases for all alternatives. Upgradient surface water will continue to be diverted around the tailings pile into the three adjacent drainages.

During operation, all contact water, including surface water runoff from the pile will continue to be collected, treated, and discharged into Hawk Inlet under the NPDES permit.

All other parts of the mine operation have been approved through other NEPA actions. Runoff from other mine related facilities, such as active production rock disposal facilities sites 23 and D are monitored under the FWMP and regulated through DEC's Waste Management Permit. All point source discharges are regulated under the NPDES permit.

Because there has been no demonstrable impact from runoff from these other sources, and because all tailings contact water will be contained, treated, and discharged throughout operation and for a number of years after closure, the total cumulative impact to surface water quality during that period is predicted to be negligible.

At the point during the post-closure period when revegetation is sufficient to minimize erosion, the surface water runoff diversion and collection system will be removed. The runoff from the pile will be directed to the southwest corner of the pile where it will combine with water from the underdrains or revert to natural courses. From here, the combined water will be managed using one of the three discharge scenarios described in Section 2.5.1. This water would only be discharged to surface waters if it

met all applicable AWQS. At this time, most road and facilities would have been removed. Discharge of water which meets all applicable AWQS, is not considered to have a negative cumulative impact to surface water quality.

Ground Water Hydrology and Quality

Under the No Action Alternative, during operations, precipitation will continue to infiltrate and percolate through the pile to the water table inside the pile, and ultimately to the wet wells. Upwelling groundwater will continue to mix with infiltrated water in the underdrains, be collected by the wet wells, and be treated prior to discharge to Hawk Inlet. Reclamation of the pile will result in a post closure continuation of the groundwater and surface water flow patterns. Water quality patterns that have developed during operations will convert to a capped pile scenario.

Water quality data from the Pit 5 area show the presence of elevated sulfate levels in the bedrock groundwater aquifer. There are no known current impacts to Cannery Creek or the adjacent high quality wetlands, and low permeability sediments are present to exclude most or all of the contact water and flow in this direction. Under this alternative, groundwater in this area would continue to have the potential to flow, as it currently does, towards Cannery Creek. There would be no effect on the water quality in the Tributary Creek drainage.

There will be no discharge of water that exceeds AWQS at the specified compliance point during operation or post closure. As discussed under surface water quality cumulative impacts above, the other aspects of the mining operation have been approved through separate NEPA actions and are regulated under the FWMP and DEC's Waste Management Permit. All point source discharges are regulated under the NPDES permit.

Given that no water that exceeds AWQS will be discharged from the tailings pile and other parts of the mine are not expected to impact groundwater, and there are no other projects to affect groundwater quality, it is not predicted that there will be cumulative impacts to groundwater quality.

Wetlands

As discussed under Wetlands in Chapter 3, the area around the Greens Creek mine contains approximately 530 acres of jurisdictional wetlands and a number of streams assumed to fall within the definition of waters of the United States. Several individual CWA Section 404 permits have been issued for mining operations in the area, including Tailings Impoundment Area (Permit No. 4-880269). Additional fill in wetlands in connection

with this project would be done under this permit or a new permit. In 1994, Three Parameters Plus, completed the analysis on jurisdictional wetland determinations and functions and values contained in the planning record. As discussed in Section 3.9, low value wetlands are abundant in the area, especially forested low value wetlands. There are no other projects in the area except other parts of the mine operation to affect wetlands. Under all alternatives, including the No Action alternative, there would be minor degrees of wetland loss. These impacts will be direct. The cumulative impacts to wetlands from this project and other aspects of the mine operation are predicted to be minor.

Vegetation

None of the vegetation loss anticipated under any alternative is considered significant on a project area or regional basis. There are no other projects proposed in the area of the proposed action that would have any effect on vegetation, therefore no cumulative effect beyond the direct impacts on vegetation previously described is anticipated.

Wildlife and Birds

There would be some loss of forested habitat under any of the action alternatives (see acreages in Section 4.7 Vegetation above), however, most of the area of the expanded pile footprint has already been cleared as part of the current permitted activities. Direct habitat losses for mammals will primarily be for small mammals using the habitats. To the extent that larger mammals (brown bears and deer) use the forest fringe adjacent to the pile, they are likely to shift their use. Given the amount of similar surrounding forested lands the impact of habitat loss would be minimal. Overall, the loss of habitat associated with the project would be relatively minor during operation of the mine and insignificant upon final reclamation.

Employees of Greens Creek are not allowed to hunt or fish in the vicinity of Greens Creek, so continuation of mine life would not cause pressure from harvesting. Thus, under all four alternatives, the effects on wildlife would continue as they are today, other than the length of time during which the mine would continue to operate. Once the mine shuts down, this habitat will gradually be restored, but harvesting pressure may increase with people hunting where they are not currently allowed.

Under any of the alternatives, the cumulative effect of the expansion of the tailings pile and the continuation of the other aspects of the mine operation would be to extend the operational life of the mine. The Forest Service Standards and Guidelines for Sitka black-tailed deer, bald eagles,

brown bear and American marten would be complied with under any of the alternatives. As previously described, direct impacts to wildlife would be minor and cumulative impacts to wildlife from continuation of all aspects of the mine operation are predicted to be minor.

Present above ground activities include hauling material from the mine to the mill site, processing, and operations related to the tailings facility. Workers arrive and leave the area on a ferry from Juneau that runs back and forth to the site. A road has been constructed to transport the workers to the mine. These activities do not affect individual migratory birds, habitats, or populations.

Other activities (approved under previous NEPA actions) include exploratory surface drilling throughout the lease area. In the past, they have occurred in forest habitats, alpine, and subalpine habitats. The activities include clearing an area to accommodate construction area for a small drilling platform. Less than one quarter acre of forested vegetation is disturbed. The platform is removed once the drilling operation ends. There is potential that some nesting birds may be disturbed if the drilling occurs during the nesting season and the drilling occurs in forested habitats. The overall suitability of habitat for migratory birds has remained intact, because the clearings are small.

There are no reasonably foreseeable future activities planned in the immediate future that would affect additional habitats. The Admiralty National Monument contains Congressionally-designated Wilderness and Non-wilderness National Forest System lands. The goal of the wilderness designation is to manage portions of the monument to protect and perpetuate natural biophysical and ecological conditions and processes. Minerals exploration and production is allowed with specific direction from the Alaska National Interest Lands Conservation Act (Forest Plan, 1997). There are no proposals to develop any large scale mines in the reasonably foreseeable future (pers. comm. Jeff DeFreest).

The forest lands are classified as unsuitable for timber production and have been withdrawn from timber production. Traditional personal wood harvesting is allowed. This use is restricted to recovering beach logs that are found along the coastline; vehicles may be used, but road construction is prohibited. Cutting of green trees is by permit only for other specific permitted projects or for emergency cutting of trolling poles (Forest Plan, 1997). These activities will not cumulatively affect migratory bird habitats.

There is little available data to assess murrelet population trends North America; however trends are considered to be downward for all

populations that rely on large commercially valuable conifers. Conservation strategies include old-growth forest reserves. These measures have been implemented with direction in the Forest Plan through a system of designated large, medium, and small old-growth reserves throughout the Tongass. Additional protection is provided with non-development land use designations. Admiralty Island National Monument is a designated Wilderness Area and timber harvest is not permitted. There are no reasonably foreseeable future actions proposed on Admiralty Island that would cumulatively affect marbled murrelets or habitat.

Marine Mammals

There are no past, planned, or reasonably foreseeable future activities which would have a cumulative impact upon marine mammals in the area. Risks to these higher trophic level mammals could occur primarily through transfer of metals from prey item, however, such impacts are not likely, due to the transient nature of these species in Hawk Inlet, (OIO and RTI, 1998). There are no activities associated with any of the proposed actions for this project, including associated traffic from ore barges or ships that would be expected to adversely affect any of these species. No activity associated with any of the alternatives would constitute harassment or a taking under Marine Mammal Protection Act.

Threatened and Endangered Species

None of the alternatives would have any impact on threatened and endangered or Alaska Region sensitive species of plants, birds, or land mammals, or fish because none are in the area, nor are any critical habitat designations for such species. Therefore there will be no cumulative impacts on any threatened and endangered or Alaska Region sensitive species of plants, birds, land mammals, or fish.

Federally listed marine mammals include the humpback whale and Steller sea lion. Northern sea otters are a candidate species for T&E status. Both Steller sea lion and humpback whales occasionally visit Hawk Inlet. Risks to these higher trophic level mammals could occur primarily through transfer of metals from prey item, however, such impacts are not likely, due to the transient nature of these species in Hawk Inlet, (OIO and RTI, 1998). Northern sea otters are rarely seen east of Icy Strait.

No critical habitat for any listed or candidate marine mammal species exists in the study area. No activity associated with any of the alternatives would constitute harassment or a taking under the Endangered Species Act or the Marine Mammal Protection Act.

Marine and Aquatic Habitats, Biota, and Essential Fish Habitat

During operation and for a period after closure, there will be no changes in the existing outfall that discharges water collected from the pile into Hawk Inlet. With suspension of milling activities at closure, the volume of water treated and discharged will appreciable decrease. Any water discharged, either directly through the existing pipeline/diffuser system, or via surface water or groundwater routing, will continue to be required to meet the Alaska water quality standards (AWQS) for (a) water supply; (b) water recreation; (c) growth and propagation of aquatic life and wildlife; and (d) harvesting for consumption of raw aquatic life. This will be achieved naturally or by using water treatment if required to meet AWQS. No discernable structural effects are expected on marine habitats, subtidal substrata and biota, *benthic* (sea bottom) habitats in the project area, intertidal sands, submerged sill habitats, kelp habitats, rocky habitats, or fresh water fish habitats, thus no direct effects to EFH is expected. Heavy metal accumulation in marine sediments at the ship loading dock and possibly near outfall 002 are anticipated under all alternatives. Metals may accumulate in marine biota. Additionally, there is a slight potential for impacts to marine resources from a spill of fuel or hazardous materials release. The longer the mine operates, the longer this slight risk exists. Other aspects of the continued operation are unlikely to have any impact on EFH. Overall, the risks of cumulative impacts to EFH are predicted to be negligible to minor.

Heritage Resources

There are no known heritage or historical sites that would be affected by from direct, indirect, or cumulative sources.

Subsistence

The analysis of effects on subsistence is similar to the analysis under Wildlife above. As described in Chapter 3, the reliance on subsistence resources in this area is minor. As described in the Wildlife section, each of the alternatives would have negligible effects on fish and wildlife resources. Therefore, none of the alternatives, in combination with other aspects of the mine would decrease the abundance or availability of subsistence resources. None of the alternatives would impact subsistence users' access to or quality of fish or wildlife resources. For these reasons, the project would not have any significant cumulative impact to subsistence use of wildlife, fish, or other foods.

Recreation

Each alternative would have negligible impact on recreation. Existing tourism to Angoon, which centers on fishing, big game guiding, camping, bear watching, and canoeing, would be expected to continue with minimal, if any, impacts from any of the alternatives. The same is true for sightseeing and fishing tours centered on Admiralty Creek and Oliver Inlet, on the western side of Admiralty Island. The effect of the expansion of the tailings pile, together with other aspects of the mine operation, is to allow the continuation of the operational life of the mine. No cumulative impacts are expected to recreational opportunities.

Socioeconomics

The cumulative impacts of the four alternatives depend on the life of the mine anticipated under each alternative. Socioeconomic effects are measured in terms of prolonged or additional economic benefits. As discussed under temporal and spatial boundaries earlier in this section, the temporal boundaries for the socioeconomic cumulative impacts appropriately include the entire City and Borough of Juneau.

While Greens Creek currently has enough tailings disposal capacity for approximately two years of operation, the mine has proven reserves that indicate a remaining life of 12 years and an expected 10 additional years based on reasonably foreseeable discoverable reserves. Alternative A, the no action alternative, would result in closure of the mine after about two years. Alternatives B, C, and D would provide enough tailings disposal area to meet the mine's needs for its remaining 12-years of proven reserves and 10 additional years of reasonably foreseeable expected discoveries. The socioeconomic effects, measured as prolonged benefits, could include (for example) annual direct payroll of $26 million. If a particular alternative increases the mine's life by twenty years, the economic effect would include $520 million in total additional payroll to the mine's employees.

When the mine closes, Juneau's economy will lose the benefit of the direct employment and payroll, in addition to the indirect and induced employment and payroll generated through the consumption of local goods and services by mine employees and their dependents.

The impact of mine closure also includes loss of property tax revenues to the City and Borough of Juneau. In 2001, Greens Creek paid $672,000 in property taxes. If the mine is forced to close because of loss of tailings disposal capacity, the value of the mine is reduced to its salvage value—a fraction of its value with adequate tailings disposal capacity.

In addition to the timing of the mine closure, the impacts of alternatives also differ in the relative impact on the economy. Juneau's economy is expected to grow slowly through 2018, at an annual rate of about 0.6 percent, according to Alaska Department of Labor and Workforce Development projections.[6] Therefore, mine closure in the near-future would have a slightly greater relative impact in Juneau than mine closure in the more distant future. Two years from now, Juneau's population would be about 2 percent above the current level. In 12 years, Juneau population would be about 9 percent above today's level. Though the difference is relatively small, this suggests that Juneau's economy could better absorb the economic impacts of mine closure in the more distant future.

The cumulative impact of the expansion of tailings pile in conjunction with the continued operation of the other aspects of the mine operation is considered minor to significantly positive. The Greens Creek mine is Juneau's largest private employer, but the economy of Juneau continues to be driven by government. With the State's current fiscal situation, and its attendant impacts to Juneau employment, there is little danger of overheating Juneau's economy even if all potential projects, including the Kensington Mine and the Juneau Access project came to fruition.

4.17.6 Effects of Short-Term Uses on Long-Term Productivity

Section 102 of NEPA requires that EIS's include "the environmental impacts of alternatives including...the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity." Under all alternatives, the Greens Creek mine site would be restored to pre-mining conditions and productivity. Surface water hydrology and aquatic habitat, as well as wildlife habitat, would generally be reestablished after closure. Revegetation would occur throughout the site and should eventually approximate pre-mining conditions. Under all alternatives, there would be some permanent wetland loss. Reclaimed wetlands should provide similar functions and values to those lost. Overall, the reclamation of the site would create a wider diversity of habitat types (wetland and upland) than currently present.

6. Alaska Department of Labor and Workforce Development, Research and Analysis Section, Demographics Unit.

4.17.7 Irreversible and Irretrievable Commitment of Resources

An irreversible commitment of resources applies to the loss of non-renewable resources (e.g., minerals or heritage resources) and to resources that are only renewable over a long period of time (e.g., soil productivity). Irretrievable commitments apply to losses of renewable resources and to situations in which a resource can be irretrievably (temporarily) lost, but the action is not irreversible.

Permitting an expansion of the tailings pile will allow the continuation of the operational life of the mine. Continued operation of the mine will continue an irreversible commitment of non-renewable resources through the extraction, milling, and exportation of ore concentrate and the mining of associated waste rock and borrow material.

Alternative B would result in the irreversible commitment of 22.1 acres of low value wetlands. Alternative C would result in the irreversible commitment of 10.2 acres of low value wetlands. Alternative D would result in the irreversible commitment of 42.5 acres of low value wetlands and 0.7 acres of moderate value wetlands.

Visually, all alternatives will cause irretrievable and irreversible commitments of form, line, color, and texture contrast between the tailings pile and surrounding vegetation. Reclamation and natural succession of vegetation would be expected to eventually mitigate most long-term visual impacts.

No other irreversible commitment of resources or irretrievable commitments of renewable resources are expected.

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Chapter 5
Lists

5 Lists

5.1 List of Preparers

The United States Forest Service, Juneau Ranger District is the lead agency for preparation of the Greens Creek Mine Tailings Disposal Final Environmental Impact Statement (FEIS). Cooperating agencies are the Environmental Protection Agency and the U.S. Army Corps of Engineers. Michael Baker Jr., under a third-party agreement between the Forest Service and Kennecott Greens Creek Mining Company, prepared this EIS; an interdisciplinary team of subcontractors completed various sections. Individuals are listed by contributing company or agency and their degrees, years of experience, and project role are shown.

Preparer	Degrees/Years of Experience	Project Role
	Michael Baker Jr.	
McKie Campbell	B.A., Political Science Years of Experience: 22	EIS Project Manager, Public Involvement, Threatened and Endangered Species
Brad Campbell	B.A., Political Science Years of Experience: 5	EIS Assistant Project Manager
Carol Gibson	B.A., Urban Planning Years of Experience: 19	Publication Specialist
	Terra Nord	
Mike Smith	Ph.D., Natural Resource Management M.S., Wildlife Management B.S., Wildlife Management Years of Experience: 34	EIS Assistant Project Manager, Writing, and Wildlife, Threatened and Endangered Species
	Tileston & Associates	
Jules Tileston	M.S., Ecology/Wildlife Management B.A. Biology and Geology Years of Experience: 38	NEPA Compliance
	Water Engineering Technologies	
Scott I. Benowitz	B.S., Civil Engineering / Engineering Mechanics Years of Experience: 16	Hydrology, and Water Quality

5 List of Preparers

Preparer	Degrees/Years of Experience	Project Role
	Schafer Limited	
William Schafer	Ph.D., Soil Science M.S., Soil Science B.S., Watershed Science Years of Experience: 28	Hydrology and Water Quality
	J. M. Munter Consulting	
James Munter	M.S., Geology B.S., Geology and Math Years of Experience: 25	Groundwater Hydrology
	Buell & Associates, Inc.	
James W. Buell	Ph.D., Biology B.A., Biology Years of Experience: 33	Fisheries Biology
	Oceanus Alaska	
Michelle Ridgway	B.S., Marine Biology M.S. 2002 (pending), Marine Ecology Years of Experience: 11	Oceanography Marine Mammals Essential Fish Habitat Marine Life
	M. C. Metz & Associates	
Michael Metz	M.S., Hard Rock Geology / Minerals Exploration B.S., Soft Rock Geology / Engineering Geology Years of Experience: 32	Geology, Soils, Geotechnical, and Seismicity
	Bridge Net	
Paul Dunholter	B.S., Civil Engineering Years of Experience: 21	Noise
	McDowell Group	
Jim Calvin	M.S., Mineral Economics B.S., Geology Years of Experience: 15	Socioeconomics
	Stephen R. Braund & Associates	
Roger Harritt	Ph.D., Anthropology M.S., Art History B.A., Fine Arts	Cultural Resources

Preparer	Degrees/Years of Experience	Project Role
	Years of Experience: 23	
	Dunn Environmental	
Art Dunn	B.S., Earth Sciences Years of Experience: 18	Wetlands Analysis, Vegetation, Threatened and Endangered Species
	Hoefler Consulting Group	
Alan Tribovich	M.S., Meteorology B.S., Meteorology B.S.Ed., Secondary Education Years of Experience: 22	Air Quality
	Land Design North	
Dwayne Adams	B.S., Landscape Architecture Years of Experience: 24	Visual and Land Use
	U.S. Forest Service	
Dave Cox	B.S. Geology Years of Experience: 2	Hydrologist
Eric Ouderkirk	M.L.A., Landscape Architecture M.U.P., Urban Planning Years of Experience: 14	EIS Project Coordinator
Laurie Thorpe	B.S. Recreation & Natural Resources Management Years of Experience: 18	EIS Project Coordinator
	U.S. Environmental Protection Agency	
Bill Riley	B.A., Human Biology Years of Experience: 28	Project Lead for EPA
Cindi Godsey	B.S., Mining Engineering MBA Years of Experience: 11	Water Quality Lead for EPA (NPDES Permit Writer)
David Frank	Ph.D., Geological Sciences Years of Experience: 30	Geology/geochemistry lead for EPA
	U.S. Army Corps of Engineers	
John C. Leeds, III	B.S., Biological Science Years of Experience: 18	Juneau Field Office Manager

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5.2 List of FEIS Recipients

The following agencies, organizations, and persons were either notified of the availability of the Greens Creek Mine Tailings Disposal FEIS or were sent a copy.

Agencies

State of Alaska

Advisory Council on Historic Preservation, Planning and Review, Director

Department of Environmental Conservation, Division of Environmental Health (Ed Emswiler)

———, Division of Air and Water Quality (Pete McGee, Kenwyn George)

Department of Law (Cameron Leonard)

Department of Natural Resources (Charles Cobb, Joe Donohue, Ed Fogels, Ed Fogels, Stan Foo, Steve McGroarty, Jim Vohden)

Office of Housing & Urban Development, Field Environmental Contact

Office of Management & Budget, Division of Governmental Coordination (Randy Bates)

United States (U.S.)

Army Corps of Engineers, Alaska District (Michael E. Holley, John Leads)

Coast Guard, Marine Safety, Security, and Environmental Protection

Department of Agriculture, Agricultural Research Service, National Agricultural Library

———, Animal & Plant Health Inspection Service (APHIS) PPD/EAD, Deputy Director

———, Forest Service, Admiralty Island National Monument

———, Alaska Region, Ecosystem Planning Director, Print Specialist, Regional Forester, Ecosystem Management Coordination, Director

———, Craig, Hoonah, Juneau, Ketchikan-Misty, Petersburg, Sitka, Thorn Bay, Yakutat, and Wrangell Ranger District

———, Chugach National Forest, Supervisors Office

———, Tongass National Forest, Ketchikan, Petersburg, and Sitka Supervisors Office

———, Office of Civil Rights

———, Natural Resources Conservation Service, National Environmental Coordinator

Department of Commerce, National Marine Fisheries, Office of Protected Resources Division (James Balsiger, Katharine Miller)

Department of Energy, Office of Environmental Compliance, Director

Department of Interior, Bureau of Land Management, Alaska State Office

———, Fish and Wildlife Service (Richard Enriquez, Deb Rudis)

———, National Park Service, Alaska Area Region

———, Office of Environmental Policy & Compliance, Director

———, Office of the Secretary

Department of Transportation, Environmental Division, Assistant Secretary for Policy

———, Federal Aviation Administration, Alaskan Region Headquarters

———, Federal Highway Administration, Western Region

———, Federal Railroad Administration, Transportation and Regulatory, Affairs, Research and Special Program Administration (RSPA)

Environmental Protection Agency (Cindi Godsey, Bill Riley, EIS Review Coordinator, Office of Federal Activities)

Navy Observatory, Environmental Protection Division, Naval Oceanography Division

Libraries

Community Libraries: Kake, Kasaan, Thorne Bay

Kettleson Memorial Library

Public Libraries: Craig, Douglas, Elfin Cove, Haines, Hollis, Hyder, Ketchikan, Juneau, Mendenhall Valley, Pelican, Petersburg, Skagway, Tenakee Springs, Wrangell

Sitka Conservation Society

Native Organizations

Angoon Community Association (Ed Gambell, Marlene Zuboff)

Central Council of Tlingit and Haida Indian Tribes (Ed Thomas)

Douglas Indian Association

Media

KTOO (Anne Sutton)

Organizations and Businesses

Alaskans for Juneau (Skip Gray, Aaron Brakel, Irene Alexakos)

Audubon Society, Juneau (Sue Schrader, Chris Kent)

Audubon Alaska, Anchorage

Bear Creek Outfitters, Inc.

Campaign to Safeguard America's Waters (Gershon Cohen)

Cascadia Wildlands Project (Gabriel Scott)

Center for Science in Public Participation (Amy Crook, Dave Chambers)

City and Borough of Juneau (Peter Freer)

Defenders and Friends of Admiralty Island (K.J. Metcalf)

Earth Justice Legal Defense Fund (Eric Jorgensen, Tom Waldo)

Friends of Berners Bay (Dana Owen)

Goldbelt Incorporated (Gary Droubay)

Kennecott Greens Creek Mining Company (William F. Oelklaus, Tom Zimmer)

Kootznoowoo Incorporated (Bob Hamilton)

Lynn Canal Conservation Inc. (Bruce Baker, Tim June)

Mineral Policy Center (Bonnie Gestring)

Point Adolphus Seafoods (James Mackovjak)

Sealaska Corporation (Pete Huberth, Chris E. McNeil, Michele Metz)

Sierra Club, Juneau Group (Mark Rorick, Richard Hellard)

Southeast Alaska Conservation Council (Kate Hall, Buck Lindekugel)

Taku Conservation Society (Mary Lou King, Nancy Waterman)

Territorial Sportsman

Trout Unlimited (Mitch Lorenz)

WMAP (Roger Flynn)

5 List of FEIS Recipients

Individuals

Samual McBean

Bill and Beatrice Booth

William Brent

Betsy Burdett

William M. Cox, MD

Laurie Ferguson Craig

Andrea Doll

Dr. I. Cannon Geary

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Molly Hodges

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William Leighty, Nancy Waterman

Deborah L. Levine

Joyce Levine

Debbie Manion

Douglas Mertz

Lance Miller

Ben Mitchell

Lisa Murkowski, U.S. Senator

Daniel Nelson

Maryellen Oman

Jerry Reinwand, LCC

Lynn J. Schimmels

Ted Stevens, U.S. Senator

John Swanson

Curtis Terrall

Victor Voit

Cynthia Wayburn

Don Young, U.S. Representative

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5.3 Abbreviations and Acronyms

AAQS	Alaska Ambient Air Quality Standards
ACMP	Alaska Coastal Management Program
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADOL	Alaska Department of Labor
AGP	Acid-Generating Potential
ANILCA	Alaska National Interest Lands Conservation Act
ANP	Acid-Neutralizing Potential
APS	Alaska Public Survey
ARD	Acid Rock Drainage
AWQS	Alaska Water Quality Standards
BAT	Best Available Technology
BPJ	Best Professional Judgment
CBJ	City and Borough of Juneau
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cm	Centimeter
COE	U.S. Army Corps of Engineers
cu ft	Cubic feet
cu yd	Cubic yards
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
DGC	Division of Governmental Coordination
DIPAC	Douglas Island Pink and Chum Hatchery
DST	Dry short tons
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESU	Endangered Species Units
FEIS	Final Environmental Impact Statement
FWMP	Fresh Water Monitoring Program
gpm	Gallons per minute
GPO	General Plan of Operations

HAPC	Habitat areas of particular concern
HDPE	High density polyethylene
IMPLAN	Impact analysis for Planning
IRI	Integrated Resource Inventory
KGCMC	Kennecott Greens Creek Mining Company
km	Kilometers
LUD	Land Use Designation
MBJ	Michael Baker Jr., Inc.
MIBC	A frothing reagent used in the mill flotation process
MOU	Memorandum of understanding
NAWS	Non-Agricultural Wage and Salary
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NNP	Net Neutralization Potential
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units
NWI	National Wetlands Inventory
PM_{10}	10 micrometers
ppt	Precipitate
PRC	Pyrite Reduction Circuit
PSD	Prevention of Significant Deterioration
RM	Road mile
ROD	Record of Decision
SIPX	Xanthate
TLMP	Tongass Land Management Plan
TSS	Total Suspended Solids
USACE	U.S. Army Corps of Engineers
USDA FS	United States Department of Agriculture Forest Service
USFWS	United States Fish and Wildlife Service
VQO	Visual Quality Objective

5.4 Glossary

Acidity	Earth materials that contain sulfide minerals or other materials that, if exposed to air, water, or weathering processes, form acids that may create acid drainage. A solution of pH less than 7.0 at 25 degrees C.
Acid Rock Drainage (ARD)	A leachate having characteristic water chemistry resulting from geochemical conditions occurring within the tailings or pyrite concentrate. Typical ARD chemistry includes high levels of acidity, dissolved solids (including sulfate), low pH, and in some situations can include elevated metal concentrations. ARD may be harmful to aquatic organisms and to drinking water supplies.
Alkaline	Having the qualities of a base; basic (pH greater than 7.0).
Alternatives	For NEPA purposes, alternatives to the Proposed Action examined in an EIS. The discussion of alternatives must "sharply [define] the issues and [provide] a clear basis for choice...by the decision maker and the public" (40 CFR 1502.14).
Amphipods	Small, shrimp-like crustaceans.
Amorphous	A term applied to rocks or minerals that possess no definite crystal structure or form, such as amorphous carbon.
Anadromous	Type of fish that migrate upstream from saltwater to freshwater to spawn (breed), such as salmon, some trout and char species, and shad. Also describes the fishery or habitat used for spawning by these species.
Aquatic	Growing, living in, frequenting, or taking place in water.
Aquifer	A zone, stratum, or group of strata acting as a hydraulic unit that stores or transmits water in sufficient quantities for beneficial use.
Argillite	A compact argillaceous rock cemented by silica and having no slaty cleavage
Arsenic	A trivalent and pentavalent solid poisonous element that is commonly metallic steel-gray, crystalline, and brittle.
Base drain	A drain for water at the bottom of an impoundment or a storm runoff catchment.
Base flow	A sustained or fair-weather flow of a stream.
Baseline data	Data gathered prior to the proposed action to characterize pre-development site conditions.

Bathymetry	The measurement of depths of water in an ocean, lake, or sea.
Bedrock	Solid rock either exposed at the surface or situated below surface soil, unconsolidated sediments, and weathered rock.
Benthic	All underwater bottom terrain from the shoreline to the greatest deeps.
Bentonite	A clay which has great ability to absorb water and which swells accordingly.
Berm	An earthen embankment, dike.
Bioaccumulation	Pertaining to concentration of a compound, usually potentially toxic, in the tissues of an organism.
Bicarbonate	An acid carbonate.
Biota	All of the living material in a given area; often refers to vegetation.
Borough	An area incorporated for the purpose of self-government; a municipal corporation.
Borrow area	Earthen construction material source area such as sand and gravel, till, or top soil taken from a specific area for use in construction and/or reclamation.
Brachiopods	Phylum of shelled sessile or sedentary marine animals, commonly known as lamp shells, and characterized by a peculiar feeding organ, the lophophore. The shell consists of two parts, called valves that completely enclose the body; the external appearance of the animal is much like that of a bivalve mollusk, or pelecypod, such as a clam.
Cadmium	A tin-white, malleable, ductile, toxic, bivalent metallic element used in the electroplating of iron and steel and in the manufacture of bearing metals.
Calcite	A mineral, calcium carbonate ($CaCO_3$). One of the most common minerals; the principal constituent of limestone.
Calcium	A silver-white bivalent metallic element of the alkaline-earth group occurring only in combination
Carbonate	A compound containing the acid radical CO_3 of carbonic acid. Bases react with carbonic acid to form carbonates.
Catchment	A drainage area or basin for water.
Chromium	A gray metallic element found in the mineral chromite.

Clean Water Act (CWA)	The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act also continued requirements to set water quality standards for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.
Climatological	The prevailing weather conditions of a region averaged over a series of years.
Closure	The final stage of mining that involves closure of all mine openings, regrading, and reclamation.
Collection ditches	Channels constructed to collect and divert surface water runoff.
Colluvial	Deposit of soil and fragmentary matter at the base of a slope.
Community	The stabilized plant community on a particular site. The relative composition of species does not change so long as the environment remains the same.
Compliance Point	That point as defined by the ADEC, and or EPA that water quality is measured for compliance with water quality standards or permit conditions. This point can be at the edge of a permitted mixing zone or at the end of a discharge pipe.
Concentrate	The ore that contains the mineral sought following the concentration process (e.g., flotation, gravity).
Conifer	A broad classification of trees, mostly evergreens that bear cones and have needle-shaped or scale-like leaves; timber commercially identified as softwood.
Contact Water	Water which has come in physical contact with tailings
Context	The context in which the action will occur includes the specific resources, ecosystem, and the human environment affected. Context is considered on a site-specific project area, and regional basis. Both short- and long-term effects are relevant.
Council on Environmental Quality (CEQ)	A body established by the National Environmental Protection Act (NEPA) to draft regulations for implementing and monitoring NEPA. CEQ regulations are presented in 40 CFR 1500–1508.

Cumulative impacts	Combined impacts of the past, present and reasonably foreseeable future actions. For example, the impacts of a proposed timber sale and the development of a mine together result in cumulative impacts.
Demographics	Characteristics of human populations with reference to size, density, growth, distribution, migration, and effect on social and economic conditions.
Development Rock	Non-mineralized rock, removed from the mine, and used for construction in connection with mine development.
Dewater	The mechanical separation of solid matter from water in which it is dispersed, by such equipment as thickeners, classifiers, hydrocyclones, filters, and centrifuges.
Direct impacts	Impacts that are caused by the action and occur at the same time and place (40 CFR 1508.7). Synonymous with *direct effects*.
Discharge	The volume of water flowing past a point per unit time, commonly expressed as cubic feet per second, million gallons per day, and gallons per minute, or cubic meters per second.
Diversion	Removing water from its natural course of location, or controlling water in its natural course of location, by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump, or other structure or device.
Dolomite	The mineral group ankerite, dolomite, kutnohorite, minrecordite, and norsethite.
Dry Short Tons (DST)	A unit of weight, equivalent to 2,000 pounds or 907.20 Kilograms.
Dry tailings	Dewatered gangue and other refuse material resulting from the washing, concentration, or treatment of ground ore.
Dry tailings facility	A geotechnically-engineered embankment used for the disposal of dewatered mine tailings.
Earthquake	Sudden movement of the earth resulting from faulting, volcanism, or other mechanisms within the earth.
Effluent	A liquid, solid, or gaseous product, frequently waste, discharged or emerging from a process.
Embankment	A linear structure, usually of earth or gravel, constructed so as to extend above the natural ground surface and designed to hold backwater from overflowing a level tract of land.

Environmental Impact Statement (EIS)	A formal public document prepared to analyze the impacts on the environment of a proposed project or action and released for comment and review. An EIS is prepared, instead of an Environmental Assessment (EA), when significant environmental impacts are anticipated. Comments are requested within 45 days after the release of a Draft Environmental Impact Statement (DEIS). Comments are considered prior to making the final decision and are responded to in the Final Environmental Impact Statement (FEIS).
Engineered cover	Synthetic or organic material designed to mitigate water and air infiltration through the tailings pile.
Epibenthic	Living (under water) on the surface of the bottom.
Erosion	The wearing away of the land surface by running water, wind, ice or other agents.
Finger drains	Lateral drains that flow into a central drain.
Flotation	An ore concentration process that separates ground ore from waste in a mixture of ore, water and chemicals. When air is forced through the ore/water mixture, the chemicals cause certain minerals to adhere to the air bubbles and float to the top in a froth, thus effecting a separation.
Flotation circuit	The portion of the milling process where the flotation process occurs. See flotation.
French drains	A covered ditch containing a layer of fitted or loose stone or other pervious material.
Geotechnical	A branch of engineering that is concerned with the engineering design aspects of slope stability, settlement, earth pressures, bearing capacity, seepage control, and erosion.
Geocomposite	A manufactured material using geotextiles, geogrids, geonets, and/or geomembranes in laminated or composite form.
Geomembrane	An essentially impermeable membrane used as a liquid or vapor barrier with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure, or system.

Geochemistry	The study of the relative and absolute abundances of the elements and their nuclides (isotopes) in the Earth; the distribution and migration of the individual elements or suites of elements in the various parts of the Earth (the atmosphere, hydrosphere, lithosphere, etc.), and in minerals and rocks, and also the study of principles governing this distribution and migration.
Geotextile	A synthetic fabric used in the construction of earthen structures, such as embankments, landfills, roads, etc.
Gradient	The inclination of the rate of regular or graded ascent or descent (as of a slope, roadway, or pipeline).
Habitat	The natural environment of a plant or animal, including all biotic, climatic, and soil conditions, or other environmental influences affecting living conditions.
Heavy metals	A group of elements, usually acquired by organisms in trace amounts, that are often toxic in higher concentrations; includes copper, lead, mercury, molybdenum, nickel, cobalt, chromium, iron, silver, etc.
High density polyethylene (HDPE)	Manufactured from microbiological resistant polyethylene resins, it offers optimum chemical resistance, with weathering capabilities and stress absorption properties.
Hydrologic	Of, or pertaining to, water.
Hydroseed	A slurry of water, organic matter, and seeds (typically grasses) sprayed onto areas of bare ground to promote growth and minimize erosion.
Impermeable	Having a texture that does not permit the passage of fluids through its mass.
Impoundment	The accumulation of any form of water in a reservoir or other storage area.
Indigenous	Originating, developing, or produced naturally in a particular land, region, or environment; native.
Indirect impacts	Impacts that are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. (40 CFR 1508.8) Synonymous with indirect effects.
Infiltration	The movement of water or some other fluid into the soil through pores or other openings.
Ingress	A place for entering; a way of entrance. In underground mining there are three methods of ingress–by drift, shaft, or slope

Intensity	This refers to the severity of impact. The intensity of the action includes the type of impact (beneficial versus adverse), duration of impact (short versus long term), magnitude of impact (minor versus major), and degree of risk (high versus low level of probability of an impact occurring).
Interstitial	The pore spaces among sedimentary grains in a soft sediment.
Jurisdictional wetland	A wetland area delineated or identified by specific technical criteria, field indicators, and other information for purposes of public agency jurisdiction. The public agencies which administer jurisdictional wetlands are the Fish and Wildlife Service, Army Corps of Engineers, Environmental Protection Agency and the USDA Natural Resources Conservation Service.
Lacustrine	Wetland system associated with open water bodies such as lakes, reservoirs, and impounded rivers.
Land Use Designation (LUD)	A defined area of land specific to which management direction is applied.
Leaching	A chemical process for the extraction of valuable minerals from ore; also, a natural process by which ground waters dissolve minerals, thus leaving the rock with a smaller proportion of some of the minerals than it contained originally.
Lime	Calcium oxide. Sometimes used as an abbreviated name for any rock consisting predominantly of calcium carbonate minerals.
Limestone	A bedded, sedimentary deposit consisting chiefly of calcium carbonate.
Magnesium	A malleable and ductile silvery white metal that is used in alloys.
Marine Mammal Protection Act	Enacted in 1972 to protect and manage marine mammals and their products (e.g., the use of hides and meat). The primary authority for implementing the act belongs to the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.
Micro-site	A small specific section of a study area.
Middleground	A visual reference used to indicate the middle area in viewing a landscape, i.e. foreground, middleground, and background.

Mine drainage	Gravity flow of water from a mine to a point remote from mining operations.
Minor	Impacts that are less than significant and do not require avoidance or minimization to mitigate that effect.
Mitigation measure	Avoid the impact by not taking action; Minimize the impact by limiting the degree of magnitude of the action and its implementation; Rectify the impact by repairing, rehabilitating, or restoring the affected environment; Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action; Compensate for the impact by replacing or providing substitute resources, or by enhancing the value of an adjacent existing environment.
Mixing zone	An area between an effluent discharge point and the associated water quality compliance monitoring station.
Monitoring	A continuing testing of specific environmental parameters and of project waste streams for purposes of comparing with permit stipulations, pollution control regulations, mitigation plan goals, etc.
Monument Values	The Admiralty Island National Monument was created "...to protect objects of ecological, cultural, geological, historical, prehistorical, and scientific interest." (ANILCA, Public Law 96-487, Title V, ss 503 (c))The term "Monument Values" is not used in ANILCA and does not have a separate legal definition. The term has been used by Commenters to collectively describe the purposes and those aspects of the monument they believe are important and should be protected. Environmental standards and laws are consistent in or outside of the monument.
National Environmental Policy Act (NEPA)	National charter for protection of the environment. It establishes policy, sets goals, and provides means for carrying out the policy. 40 CFR 1500–1508 are the regulations for implementing the Act.
National Historic Preservation Act (NHPA)	An Act to Establish a Program for the Preservation of Additional Historic Properties throughout the Nation, and for Other Purposes. (16 USC Sec. 470)
National Pollutant Discharge Elimination System (NPDES)	A program authorized by sections 318, 402 and 405 of the Clean Water Act, and implemented by regulations 40 CFR 122. The NPDES program requires permits for the discharge of pollutants from any point source into waters of the United States.

Negligible	Impacts on subject resources may occur as a result of project activities, but are not measurable.
NEPA process	All measures necessary to comply with the requirements of Section 2 and Title I of NEPA.
Non-point source pollution	Pollution caused by sources that are non-stationary. In mining, non-point air pollution results from such activities as blasting and hauling minerals over roads, as well as dust from mineral stockpiles, tailings, and waste dumps prior to mulching and/or revegetation.
Nephelometric Turbidity Units (NTU)	Depending on the method used, the turbidity units as NTU can be defined as the intensity of light at a specified wavelength scattered or attenuated by suspended particles or absorbed at a method-specified angle, usually 90 degrees, from the path of the incident light compared to a synthetic chemically prepared standard.
None	No impacts are anticipated when subject resources are not present or activities are not expected to affect those resources that are present.
Operating plan	Submitted by the mining operator, the operating plan outlines the steps the mining company will take to mine and reclaim the site. The operating plan is submitted prior to starting mining operations. Synonymous with the term mining plan (36 CFR, part 228).
Ore	Any deposit of rock from which a valuable mineral can be economically extracted.
Ore body	Generally, a solid and fairly continuous mass of ore, which may include low-grade ore and waste as well as pay ore, but is individualized by form or character from adjoining rock.
Ore reserve	Ore of which the grade and tonnage have been established with reasonable assurance by drilling and other means.
Organic matter	Material composed of once-living organisms (carbon compounds).
Orographic	The rain shadow effect; as air is forced upward over mountains, as it cools water vapor condenses and rains out. Dry air flows down the leeward side of mountains promoting evaporation.
Outfall	A structure (e.g., pipeline) extending into a body of water for the purpose of discharging a waste stream, storm runoff, or water.

Oxidation	A chemical reaction caused by exposure to oxygen that results in a change in the chemical composition of a mineral.
Palustrine	Of, or relating to, shallow ponds, marshes, or swamps.
Paste backfill	The disposal of thickened mine tailings, after mixing with cement, in underground mines to provide wall or ground support.
Peak flow	Highest flow; can be quantified as daily or instantaneous.
Permeability	The capacity of a material for transmitting a fluid. Degree of permeability depends upon the size and shape of the pores, their interconnections, and the extent of the latter.
Phreatic	Of, or relating to, groundwater.
pH	A measure of the acidity or alkalinity of a material, liquid, or solid. pH is represented on a scale of 0 to 14; 7 represents a neutral state; 0 represents the most acid; and 14 the most alkaline.
Phyllite	A foliated metamorphic rock that is intermediate in composition and fabric between slate and schist.
Phytoplankton	The photosynthesizing organisms residing in plankton.
Plan of Operations	See Operating plan.
Point source	Stationary sources of potential pollutants.
Pollution	Human-caused or natural alteration of the physical, biological, and radiological integrity of water, air, or other aspects of the environment producing undesired effects.
Polychaete	Any of a class of mostly marine, annelid worms, having on most segments a pair of fleshy, leg-like appendages bearing numerous bristles.
Portal	The entrance to a tunnel or underground mine.
Potentiometric surface	Surface to which water in an aquifer would rise by hydrostatic pressure.
Precipitate	The material that settles from a liquid solution when a particular substance is added to the solute.
Project area	The area within which all surface disturbance and development activity would occur.
Public scoping	Scoping is an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action (40 CFR 1501.7).

Pyrite	A common mineral consisting of iron disulfide (FeS_2) with a pale brass-yellow color and brilliant metallic luster, sometimes known as "fool's gold." It is burned to make sulfur dioxide and sulfuric acid.
Pyritic	Relating to or resembling pyrite, a common mineral; iron disulfide.
Quarry	An open or surface mineral working site, usually for the extraction of building stone, as slate, limestone, etc. It is distinguished from a mine because a quarry usually is open at the top and front, and, in ordinary use of the term, by the character of the material extracted.
Quicklime	The term is used loosely for calcium hydroxide (as in hydrated lime)
Reclamation	Returning an area to resemble pre-mining conditions by regrading and reseeding areas disturbed during mining activity.
Reclamation Material	Topsoil and organics.
Record of Decision (ROD)	A document that discloses the decision on an Environmental Impact Statement and the reasons why the decision was made; it is signed by the official responsible for implementing the identified action. The environmental consequences disclosed in an EIS are considered by the responsible official in reaching a decision (40 CFR, 1505.2).
Revegetation	The process of restoring or replacing the botanical species upon an area disturbed by mineral operations. Revegetation is a customary requirement for reclamation of a mineral operation.
Riffle	A ripple on the shallow surface of a stream.
Riparian	A type of ecological community that occurs adjacent to streams and rivers. It is characterized by certain types of vegetation, soils, hydrology, and fauna and suited to conditions more moist than that normally found in the area.
Riprap	A layer of large rock placed together to prevent erosion of embankments, causeways, or other surfaces.
Riverine	Of, or relating to, rivers, creeks, and streams.
Runoff	Precipitation that is not retained on the site where it falls, and not absorbed by the soil; natural drainage away from an area.
Salinity	A measure of the dissolved salts in seawater.

Salmonids	Fish species (salmon, trout, and char) that belong to the same family; salmonidae.
Saturation	The extent or degree to which the voids in a material contain oil, gas, or water. Usually expressed in percent related to total void or pore space.
Scoping	Requires examining a proposed action and its possible effects; establishing the depth of environmental analysis needed; determining analysis procedures, data needed, and task assignments.
Scoping Open Houses	Provides a forum to listen to and record the public's comments about the proposed project as described in the scoping document.
Scoping Process	An integral part of environmental analysis. Scoping requires examining a proposed action and its possible effects; establishing the depth of environmental analysis needed; determining analysis procedures, data needed, and task assignments. The public is encouraged to participate and submit comments on proposed projects during the scoping period. Usually there is a date associated with the end or closure of the scoping period. It is that date which responses to the formal scoping statement are due; this is usually 30 days after release of the scoping statement. Concerns regarding potential environmental impacts of proposed actions are especially valuable at this early stage.
Section 404 Permit	Section 404 of the Clean Water Act specifies that anyone wishing to place dredged or fill materials into the waters of the United States and adjacent jurisdictional wetlands shall apply to the U.S. Army Corps of Engineers for approval. A permit issued by the Corps of Engineers for these activities is known as a 404 permit.
Sediment	Material suspended in liquid or air; also, the same material once it has been deposited.
Sediment pond	Structures constructed by excavation and/or by building an embankment whose purpose is to retain water and allow for settlement of fines (TSS) and reduction in turbidity.
Seepage	The slow movement of gravitational water through the soil.
Selenium	A nonmetallic element that resembles sulfur and tellurium chemically, is obtained chiefly as a by-product in copper refining, and is a photoconductive semiconductor in its crystalline form.

Sensitive species	A plant or animal listed by a State or Federal agency as being of environmental concern; includes but is not limited to threatened and endangered species.
Significant issues	Of the issues raised during the scoping process for an environmental impact statement, certain of those issues are determined to be "significant" by the lead public agency. Determining which issues are significant, and thus meriting detailed study in the EIS, is the final step of the scoping process and varies with each project and each location. Significant issues are used to develop alternatives.
Sludge	A semi-fluid, slushy, murky mass of sediment resulting from treatment of water, sewage, or industrial and mining wastes.
Slurry	A watery mixture or suspension of insoluble matter, such as mud or lime.
Spawn	To breed; especially, to breed by releasing eggs and sperm into the water.
Stockpiling	Storage of soils and/or rock material.
Storm water	Overland flow generated as a result of a storm event.
Strata	A tabular mass or thin sheet of earth of one kind formed by natural causes usually in a series of layers of varying make-up; sedimentary units.
Subgrade	A layer, stratum, or material immediately beneath some principal surface; specifically a layer of earth or rock that is graded to receive the foundation of an engineering structure. Often it is the soil or natural ground that is prepared and compacted to support, and that lies directly below, a road, pavement, building, airfield, or railway.
Subsistence use	Section 803 of the Alaska National Interest Lands Conservation Act defines subsistence use as "...The customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of the non-edible by-products of fish and wildlife resources taken for personal or family consumption; for barter, or sharing for personal or family consumption; and for customary trade."
Substrate	An under layer of earth or rock.

Succession	Changes in the plant communities composing an ecosystem as it evolves from one type to another (e.g., wetlands becoming grassy meadows; alder thickets becoming mature spruce and hemlock forests).
Sulfide	A compound of sulfur with more than one element. Except for the sulfides of the alkali metals, the metallic sulfides are usually insoluble in water and occur in many cases as minerals.
Sump	An excavation made underground to collect water, from which water is pumped to the surface or to another sump nearer the surface.
Tailings	The non-economic constituents of the ground ore material that remains after the valuable minerals have been removed from raw materials.
Third-party contractor	Neutral party, paid by the applicant, responsible for preparing NEPA documents under the direction of the lead agency.
Thiosalts	Produced in the milling of sulphide ores. Although thiosalts have a relatively low toxicity, they are oxidized by bacteria found in effluent treatment ponds and in receiving waters resulting in the production of sulphuric acid which causes impairment to fish and other aquatic communities.
Threatened species	A plant or wildlife species officially designated by the U.S. Fish and Wildlife Service as having its existence threatened and is protected by the federal Threatened and Endangered Species Act.
Tideland	Land that is overflowed by the tide but exposed during times of low water.
Till	Non-sorted, non-stratified sediment carried or deposited by a glacier.
Topography	The physical configuration of a land surface.
Turbidity	Reduced water clarity resulting from the presence of suspended matter.
Ultraviolet degradation	Breaking down of natural and synthetic materials due do ultraviolet radiation from the sun.
Understory	Foliage layer lying beneath and shaded by the main canopy of a forest.

Visual Distance Zones	Indicates the distance of the constituent from the view. The zones are determined in USDA Forest Service Agriculture Handbook Number 701, "Landscape Aesthetics-A Handbook for Scenery Management" (p4-12): Foreground (0 - ½ mile) The viewer can distinguish tree trunks, large branches, individual shrubs, clumps of wildflowers, medium-sized animals, and medium-to-large birds. Middleground (½ to 4 miles) The viewer can distinguish individual tree forms, large boulders, flower fields, small openings in the forest, and small rock outcrops. Form, texture, and color remain dominant, and pattern is important. Background (4 miles to horizon) The viewer can distinguish groves or stands of trees, large openings in the forest, and large rock outcrops. Texture has disappeared and color has flattened, but large patterns of vegetation or rock are still distinguishable, and landform ridgelines and horizon lines are the dominant visual characteristic.
Visual Quality Objective (VQO)	Objectives identified by the Forest Service for management of the visual resource. The five categories are as follows: Preservation. Activities preserve the existing visual quality for all users Retention. Activities are designed so as not to be visually evident to the casual forest visitor. Partial Retention. Activities may be evident, but will remain visually subordinate to the characteristic landscape. Modification. Activities may dominate the characteristic landscape, but will borrow from existing form, line, color and texture. Maximum Modification. Activities may dominate the characteristic landscape. Alterations appear to be natural when viewed as background (p4-80, USDAFS, 1997):
Visual Resources	The visual quality of the landscape. The Forest Service manages view sheds as a resource, establishing specific management objectives for different areas of National Forest System lands.
Waste rock	Also known as development rock, waste rock is the non-ore rock that is extracted to gain access into the ore zone. It contains no gold or only gold below the economic cutoff level.
Watershed	The entire land area that contributes water to a particular drainage system or stream.

Wetlands	Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.
Wilderness	Land designated by Congress as a component of the National Wilderness Preservation System.
Xanthates	A class of chemicals known as "collector" chemicals, which attach to floating minerals that makes it hydrophobic, normally non-capable of adhering to the froth in a flotation circuit.
Zinc	Bluish-white hard metal, occurring in various minerals, such as sphalerite.
Zooplankton	Animals that float in the water column (some of which are able to move short distances in search of food).

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5.6 Index